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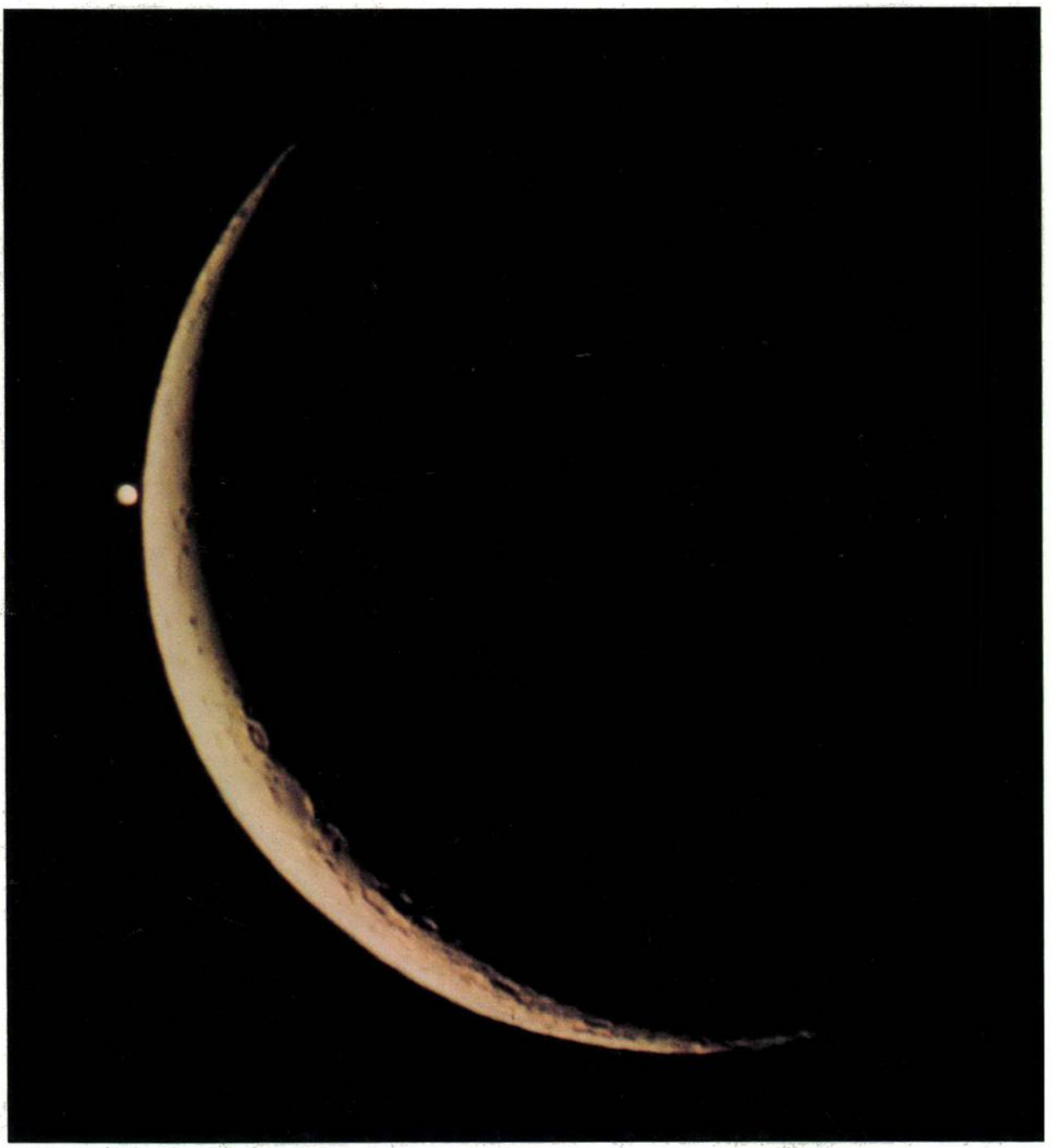

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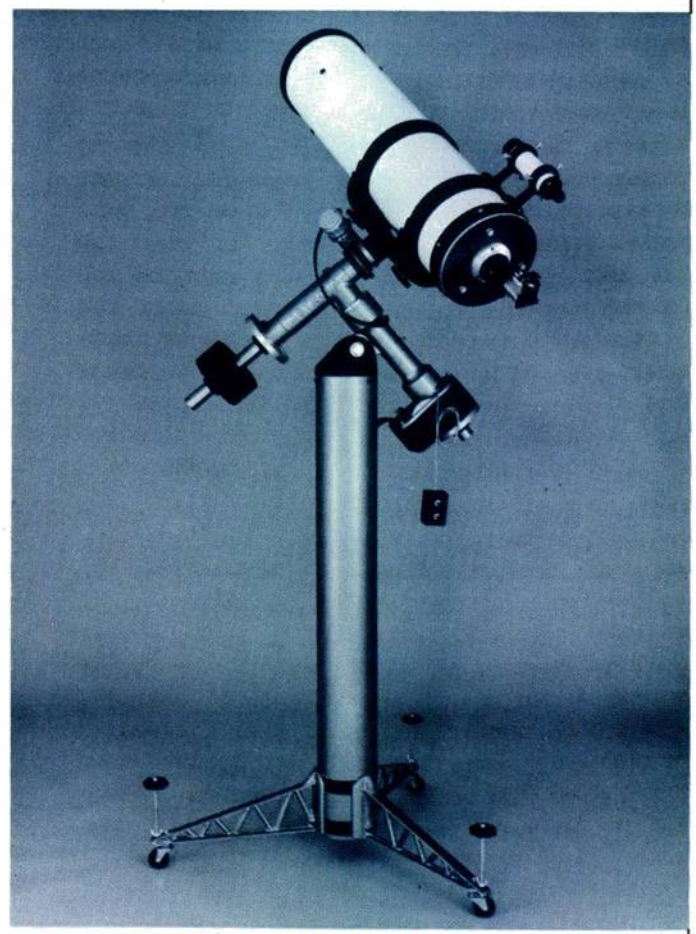

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Photograph by Fred Espenak

The two brightest objects in the night sky met in a rarely seen event — an occultation of Venus by the moon. The date was July 17, 1974, and much of eastern North America was cloudless — permitting thousands of astronomy enthusiasts to watch the moon cover Venus for about 50 minutes. Beginning at about 5:00 a.m. EDT just after this photo was taken (from Staten Island, N.Y.), Venus slipped behind the bright limb of our satellite. An eight inch f/6 reflector was used for this 1/4 second exposure on High Speed Ektachrome at the telescope's prime focus. (More Venus occultation photos appear on pages 39 and 40.)

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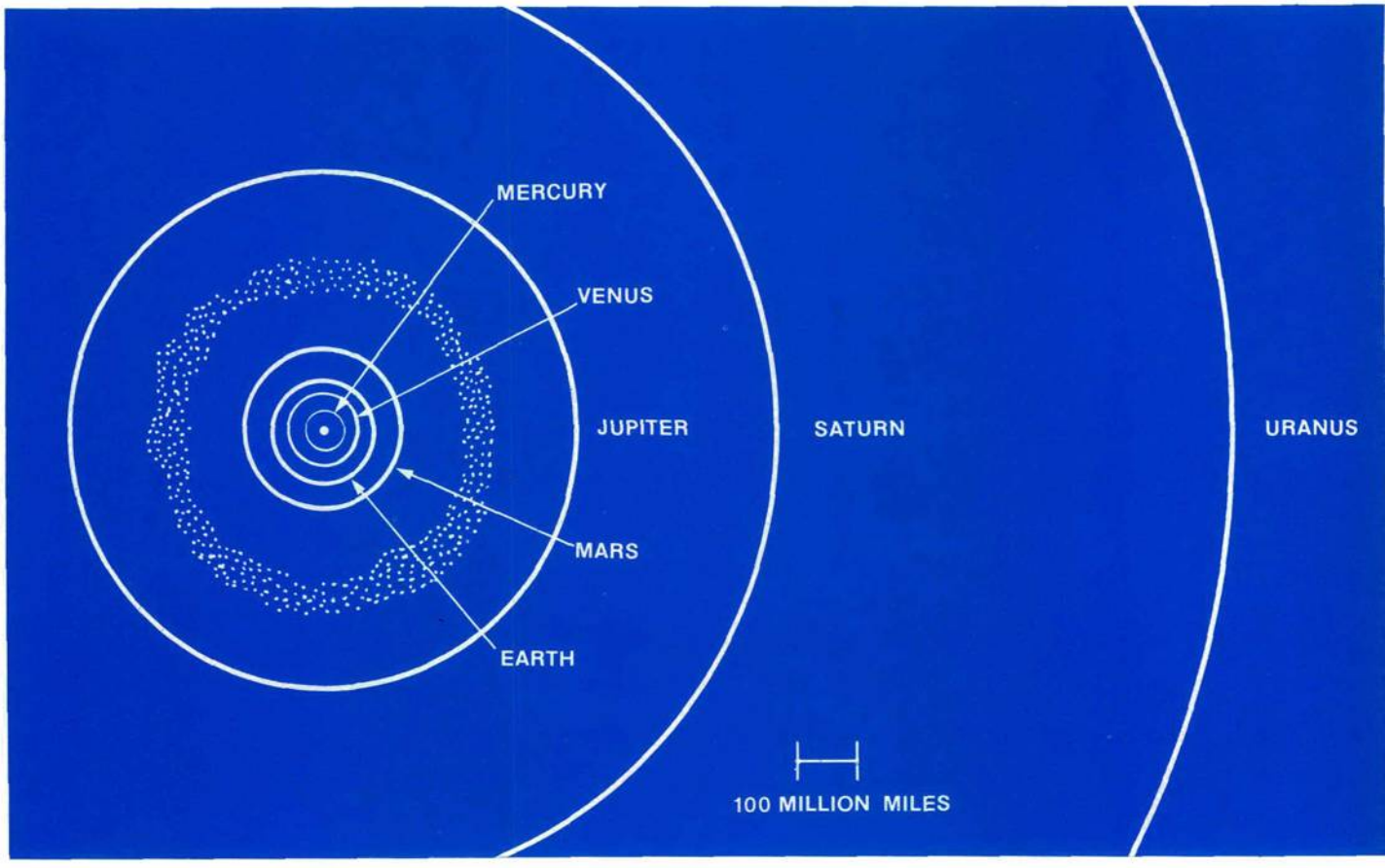
The Lost Planet?

by
Michael W. Ovenden

A 21st century expedition to Eros, a Manhattan sized asteroid, nears its climax as a shuttle craft descends toward the tiny planet's pitted surface. Of the several thousand known asteroids, Eros is one of the few that ventures nearer to Earth than even Mars or Venus. (Earth and the moon are the two bright "stars" to the right of Eros in this rendering.) The origin of Eros and the other asteroids is still widely debated by astronomers. One theory is presented in this article.

Artwork by John Clark



About 1770, Johann Daniel Titius, a professor at the University of Wittenberg, was translating into German a popular French book on astronomy. He decided to include, in a footnote to his translation, a curious little formula that he had found. If you take the numbers 0, 1, 2, 4, 8, 16 and 32, and multiply each by 3 and add 4, you get the sequence 4, 7, 10, 16, 28, 52 and 100. Titius noticed that these numbers were each very close to 10 times the distances of the then known planets from the sun (in units of Earth's distance) — provided that the number 28 was skipped, corresponding to the gap between Mars and Jupiter.

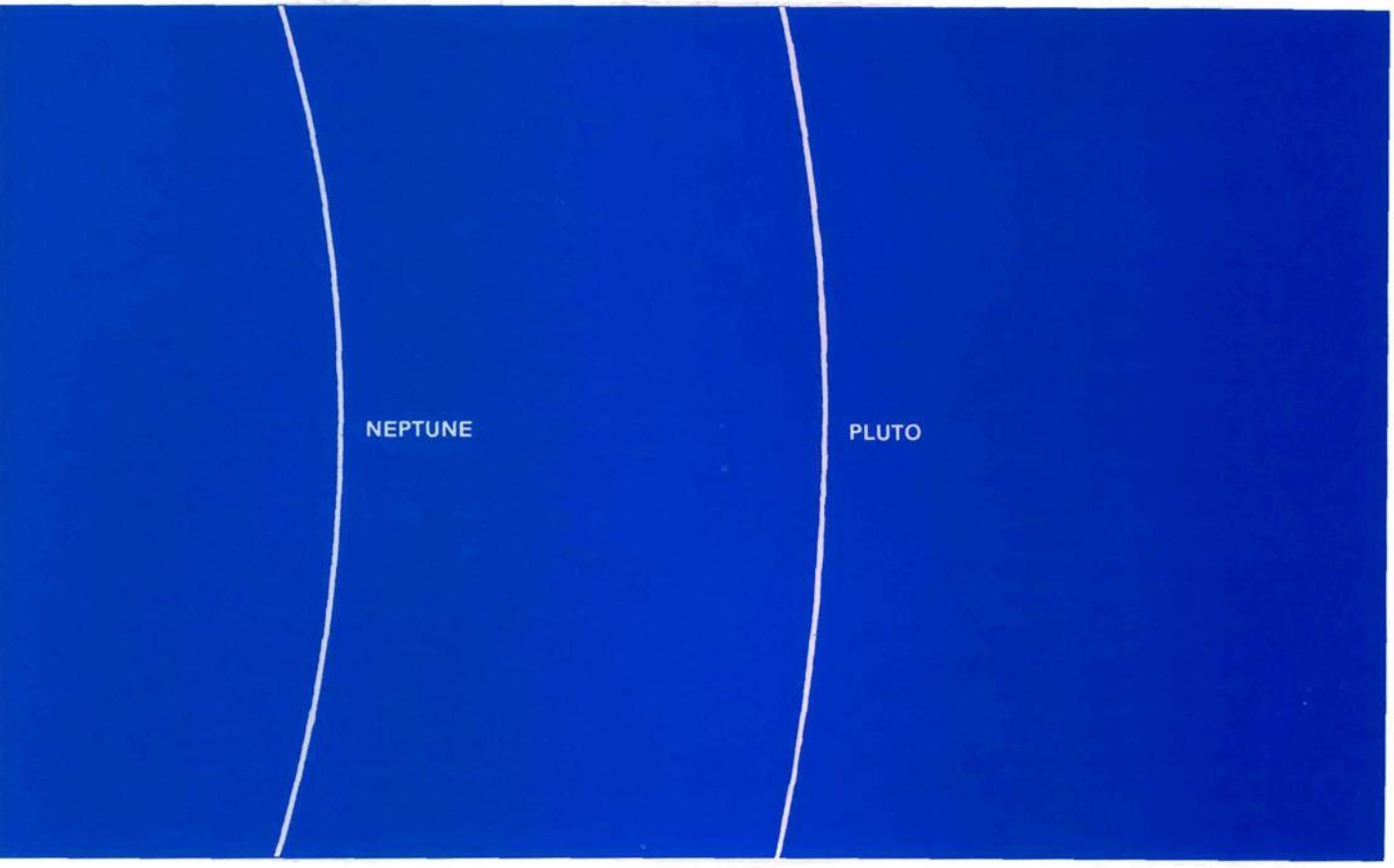
But Titius cheated on the first number of the series; it should be 1/ 2 x 3 + 4 = 5-1/ 2, which doesn't fit the distance of Mercury at all. And with the gap at place 5 as well, Titius obviously didn't take his numbers game very seriously. He died in 1776 without having had any reason to change his mind.

Then in 1781, William Herschel accidently discovered the planet Uranus. When Uranus' orbit was calculated shortly after, German astronomer Johann Elert Bode pointed out that its distance from the sun exactly fitted the next number (196) in the sequence. It is not clear whether Bode discovered the series independently, or whether he just drew attention to Titius' earlier work — but from then on, the sequence was known as Bode's law. At this point everyone became very excited, and began looking for the "missing" planet between Mars and Jupiter (at position 28). A society was formed in Germany just for this purpose.

BODE'S LAW

Planet	Distance by Bode's Law (Astronomical Units)	Actual Distance (Astronomical Units)
Mercury	0.4	0.39
Venus	0.7	0.72
Earth	1.0	1.00
Mars	1.6	1.52
Ceres (Asteroids)	2.8	2.77
Jupiter	5.2	5.20
Saturn	10.0	9.54
Uranus	19.6	19.19
Neptune	38.8	30.07
Pluto	77.2	35.50

Bode's law, although not really a law, accurately predicted the distance of Ceres and Uranus from the sun. It failed badly with the discoveries of Neptune and Pluto however. (An Astronomical Unit is the distance from Earth to the sun — approximately 93 million miles.)



The majority of the several thousand known asteroids are clustered in a zone between Mars and Jupiter. Why there is a swarm of tiny planets instead of one large one is one of the solar system's major mysteries.

After nearly 20 years of searching, nothing turned up. Enthusiasm for the project began to wane. Then on Jan. 1, 1801, Italian astronomer Piazzi (not a member of the society) accidently found what later proved to be the largest asteroid or minor planet (now called Ceres). His reward was hardly munificent; Ceres is only 600 miles across — but it did fall right at the predicted distance. Since 1801, several thousand asteroids have been discovered; most of them are very small — less than a mile in diameter. Presumably there are many others, undiscovered because they are too small to reflect enough sunlight for us to pick them up even in a large telescope.

Our patient watchers of the skies had expected a planet; instead they found nothing but a pile of interplanetary dust. So right from the start, the suggestion was made that asteroids were debris from the planet which they had hoped to find, and which had exploded at some time in the past. However the combined mass of the known asteroids adds up to less than 1/100 the mass of Earth — not much of a planet! Still, who knows how much of the planet might have been gaseous, not solid, or how much solid material was more widely dispersed?

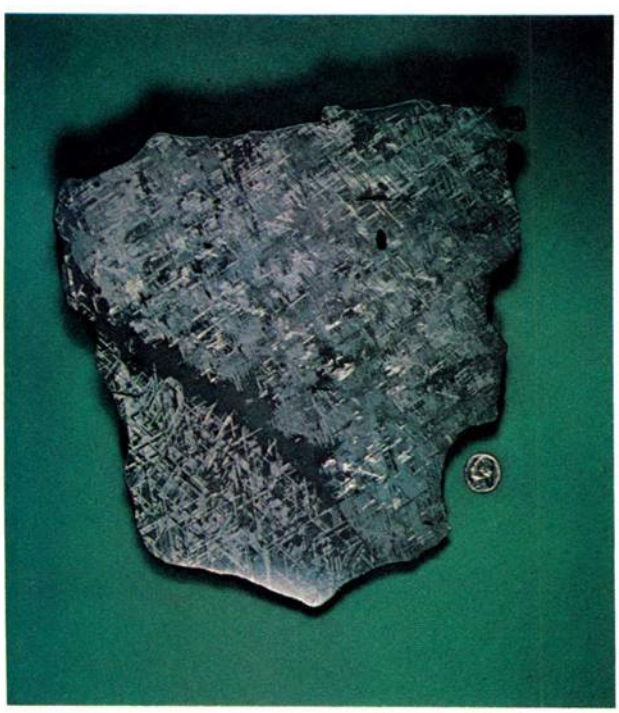
Two facts discovered later lent some credence to the idea that the asteroids came from a lost planet. First, accurate measurements have shown that many asteroids vary in brightness in a manner to be expected of light reflected from rotating, irregular, fractured chunks of rock. For example, the asteroid Eros seems to be in the form of a long cylinder (20 miles long and only 8 miles across), rotating with a period of a few hours.

The second fact concerns meteorites — chunks of space debris that survive the fiery plunge through the atmosphere. Our knowledge of the orbits meteorites had before they hit Earth tells us that most of them come from the asteroid belt. They are, in fact, just stray asteroids that happen to collide with Earth. The interiors of some meteorites show a complicated crystalline structure that could have been formed only if the material of the meteorite had once been hot, and then cooled very slowly — perhaps by only a degree in a million years! Now the rate at which a hot body can radiate away its internal heat is proportional to the area of its surface. The amount of heat a body can hold is roughly proportional to its volume. A big body cools down much more

slowly than a small one (a young baby may freeze to death where an adult would feel only chilly). For meteorite material to have cooled as slowly as a degree in a million years, it must have been at one time in a body at least 100 miles across.

With this sort of support, the idea of an exploded planet became generally accepted knowledge well over 30 years ago. As late as 1955, the Dutch astronomer Jan Oort, when discussing his ideas of a cloud of comets revolving about the sun far beyond Pluto, suggested that the comets too might have come from the same exploded planet. It surely is a dramatic picture — comets, meteorites, asteroids and all the rest of the interplanetary debris being spewed into the solar system in one gigantic planetary explosion. Still, the idea that planets may from time to time explode does not comfort the more sensitive among us who are prone to suffer from cosmic anxiety.

But there are fashions in science, no less than in raiment. In recent years the idea has become established that the planets probably had not cooled off from a molten state at their formation but had rather grown by the sticking together of smaller meteorite sized planetesimals. It therefore became more natural to think of the asteroid belt as material that failed to make a planet. After growing almost to planetary size by accretion, the proto-asteroids were broken up again into smaller pieces by colliding with each other (although just why this collision process should have operated only in the region of the asteroid belt is not clear). And the average distance of the asteroids from the sun is close to 2.8 times Earth's distance — just where Bode's law says a planet should be.



Photograph by Ivan Dryer

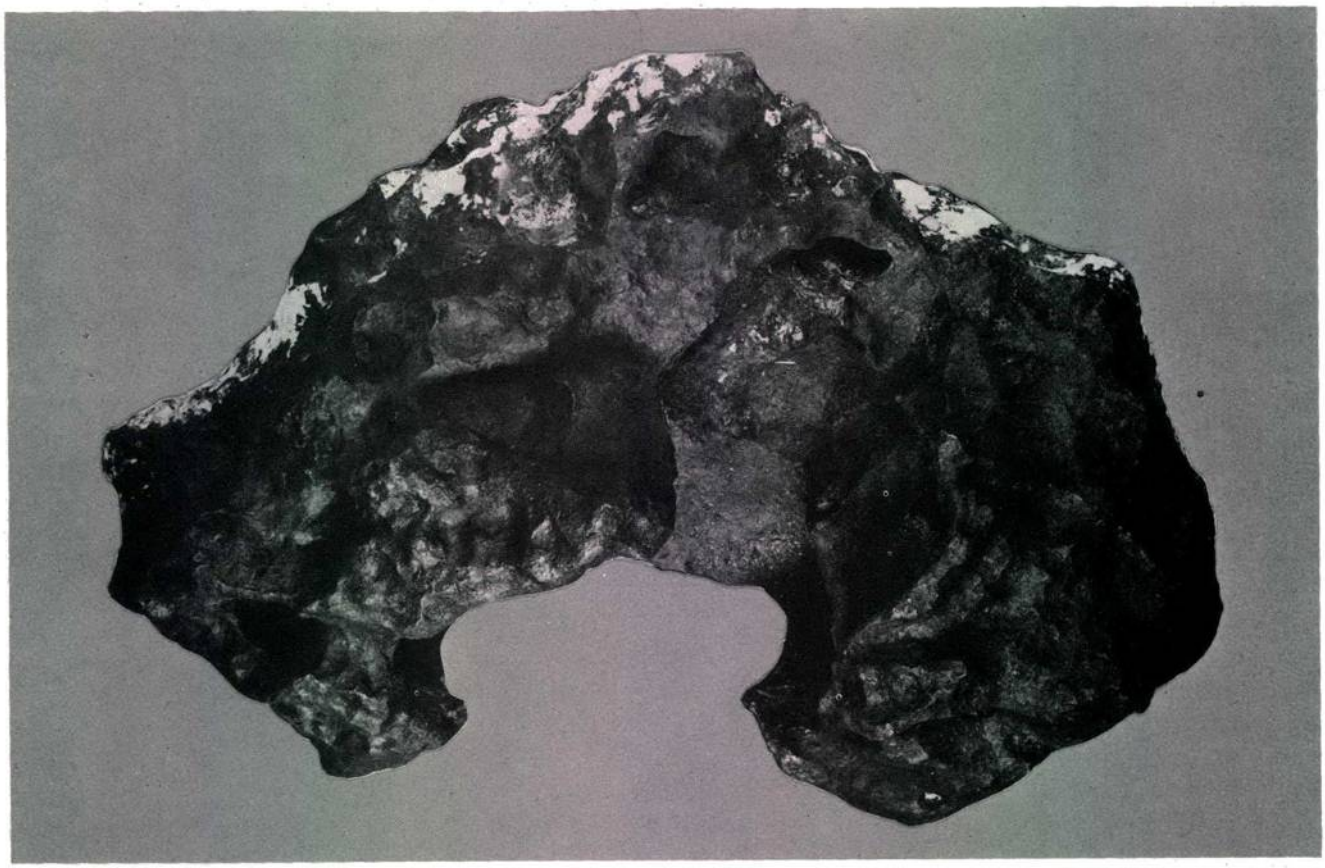
The crystalline structure of the interior of an iron meteorite indicates that it cooled from a molten state very slowly, possibly under conditions such as exist in the interior of a planet. Was this specimen once part of a planet that exploded to create the asteroids? As yet there is only circumstantial evidence and the subject is hotly debated. (Photo courtesy Ronald A. Oriti, Griffith Observatory)

So, is Bode's law really a law? Is it due to chance? Chance is a curious concept. In everyday life we use it either because we don't know the laws governing the behavior of things, or (more usually) because we ignore a wider context of influences that are actually bearing upon the course of local events. However, we do have one important clue. The distances of the moons of Uranus and the inner satellites of Jupiter can be represented by a Bode type law — the moons near the planet are bunched together while those more distant are farther apart. While Bode's law itself may not have any precise physical significance, the general way in which planets and satellites are distributed surely has some meaning.

What meaning? When you come down to basics, there are only two possibilities (or a combination of them). Either the planets have stayed where they were formed — in which case their distribution tells us something about what was going on in the early days of the solar system — or the planets have moved to their present positions.

Why should they move? A single planet revolving around the sun, if left to itself, would not change its orbit. But the planets do not leave each other alone. Just as the sun and a planet attract each other by the force of gravitation, so two planets also attract each other. Because the sun is so much heavier than the planets, the effect of one planet on the motion of another is very small; we call it a perturbation of the affected planet's orbit. These perturbations are too small to cause a significant change in a planet's distance from the sun in a million years — but the planets have existed for billions of years. What then?

Curiously enough, we don't really know. While in principle, if we know where every planet is at a given time and how it is moving, the future (and indeed the past) is wholly determined. But our mathematics isn't powerful enough to enable us to write down a formula telling us what happens. No general solution exists even for the simple case of the sun and only two planets (the famous "three body problem" that gave Newton a headache). Such formulae as we have are only approximate, and cease to be reliable if we use them for working too far back in time. They



Photograph by Paul Roques

This boulder sized iron meteorite was once part of the asteroid belt, but now it sits on exhibit at the Griffith Observatory in Los Angeles, Calif. Most museums and planetariums have displays of these extraterrestrial "visitors".

suggest that significant changes may occur in the solar system over periods of a hundred million years or so, but perhaps we are stretching the formulae too much.

On the other hand, some very general arguments show that — over an infinite time — either the pattern of the solar system repeats itself again and again, or else one or another of the planets escapes. But this supposes that the solar system is isolated from the rest of the universe — and it isn't. For example, passing stars may be responsible for sending long period comets near to the sun.

Why don't we settle the question using modern computers to calculate the past history of the solar system? We do — but there are limitations to the computers and to the formulae as we mentioned. The longest calculation of the solar system's evolution that has been made with reasonable accuracy covers less than a million years. It is not enough. And 20 years ago, even this much was far beyond the capabilities of the computers then existing.

Let's suppose that under their mutual attractions, planets do change their distances from the sun by large amounts, given enough time. Where would we expect to find them? When two planets come close together, they will perturb each other's orbits violently so the orbits will change rapidly. On the other hand, when they are far apart their mutual perturbations are small, and their orbits will change slowly. So, if we could take just one snapshot of a system of planets — and that is all our thousands of years of observation really amount to — we would expect to find the planets as far away from each other as they possibly can be.

A simple idea? Yes — that's why it is interesting. The problem is to find the distribution where the planets are as far away from each other as possible. At first sight, you might think that you could just let some of the planets escape from the solar system . They would certainly be far apart then. But the system as a whole has certain constraints. Among other things, its energy has to remain constant. It turns out, for example, that if you had three planets and the sun, and you took one planet off to infinity, you would have to put the other two closer together.

The problem, then, is: Given a star and a set of planets (or a planet and a set of satellites),

Artwork by Ron Miller

The five satellites of Uranus form a miniature solar system ranging from 77,000 to 365,000 miles from the planet. These moons are all at their "expected" distances from Uranus according to recent calculations. The major planets of the solar system, however, are not at their predicted distances from the sun according to the author. Using this reasoning, there is a "lost planet" between the orbits of Mars and Jupiter.

what is the configuration available to the system during its evolution for which the planets are, on the average, as far apart from each other as possible? This would then be the "equilibrium" configuration that we would be most likely to find the system in. It turns out it is possible to discover this configuration, at least approximately. In fact, we have some examples right in our solar system.

The configurations of the satellites of Uranus and the inner moons of Jupiter are very close to the calculated patterns. (The system of Saturn is difficult to calculate as a whole, because of the great range of satellite masses. But individual subsets of the Saturnian system seem to obey the principle also.) But when the theory is applied to the planets of the solar system, it doesn't work at all. Other calculations reveal that the five billion years the solar system has existed is plenty of time for the planets to get into their "most likely" configuration. So what's wrong? It might just happen that we are, at the moment, in a phase of evolution of the solar system between one "critical" configuration and another.

At this point the old idea about the origin of the asteroids emerges again. Is it possible that the solar system *was* close to its "expected" distribution with a planet between Mars and Jupiter, and now it is changing to a new "expected" distribution? The answer to the question is yes — if the missing planet had had a mass of about 100 times the mass of Earth, and if it had disappeared within the last hundred million years (just yesterday in the history of the solar system).

Did it really happen that way? No one can tell. The remote past is as hypothetical as the future, and any statements made about it are speculative. So, remembering that the whole investigation is necessarily speculative, how does the new perspective stack up? Here are a few examples of supporting facts:

The asteroids may be debris from a planet 100 times Earth's mass that was destroyed in a cataclysmic explosion. The cause of the explosion is unknown as is the whereabouts of most of the planet. The author believes he has evidence that the planet did indeed exist. Artwork by Rick Sternbach

Sternbach

(a) We have seen that the material of meteorites has been heated in the past and then slowly cooled. What heated it? The obvious explanation is the energy of fall-in of material as the primeval planetesimals collected into bigger bodies. The aggregate bodies must have been at least several thousands of miles in diameter in order for the heating to have been sufficient. (Other heating mechanisms have been proposed which assume very special conditions in the early stages of the solar system, and which appeal to people who do not like their proto-meteorites to be that large!)

(b) The material inside many meteorites shows magnetization, implying that it cooled in a magnetic field of the size that we would expect only on large rotating planets. We could postulate strong interplanetary magnetic fields at the right stage in the development of the solar system — but the simplest explanation is that the meteorite material was once near the surface of a large rotating planet that automatically would have had a magnetic field.

(c) The outer satellites of Jupiter move in the opposite direction to the other satellites. It is very difficult to see how such retrograde satellites could have been formed that way. Almost everyone has supposed that the retrograde satellites are captured asteroids. However, they are too deeply held by Jupiter's gravitational field to have been captured into their present orbits. Their orbits can be understood in some detail if these moons originated from a single body and were temporarily in the region of Jupiter when Jupiter suddenly increased its mass by about 100 Earth masses. Is this where most of the missing planet went? If so, how was Jupiter able to collect so much of it? Here is a field for future work.

(d) By looking at the chemical composition of meteorite material, we can find out how long the material has been in solid form (since the last "melting"). We do this by looking for products of the decay of radioactive atoms in the meteorite. This age always comes out to about 4.5 billion years, and is presumably the time since the original planet was formed. Another age can be found from the effect of cosmic ray particles on the nuclei of the meteorite atoms. Cosmic rays (which originate in supernovae explosions and other violent cosmic events) can penetrate only about a meter of meteoritic material. So the cosmic ray exposure age is the time since the meteorite became less than a meter in diameter. It happens that two quite different cosmic ray exposure ages turn up. Stony meteorites and a few iron meteorites show ages less than 40 million years, consistent with the explosion of the planet and consequent sudden production of meteorite fragments at this time. (The larger pieces would soon be broken up by collisions.) However, most of the iron meteorites show a much greater cosmic ray exposure age — about 600 million years. The ages are found assuming that all the material has been irradiated by the same, constant cosmic ray intensity. In a large planet, the stony material would lie nearer to the surface than the iron. If the planet did indeed explode, a lot of energy would have to have been released in its interior. Perhaps the iron material was exposed to streams of atomic particles from the internal explosion. This might give the iron the characteristics of 600 million years of cosmic ray exposure.

Did a large planet once orbit between Mars and Jupiter? Does the evidence presented here stand up? Right now we simply cannot say for sure, and it probably will be many years before the question is settled. Actual exploration of the asteroids, as depicted in some of the illustrations here, should ultimately give the answer. Such exploration will certainly eliminate some of the theories of asteroid origin, just as lunar exploration has reduced the possible origins of our nearest celestial neighbor.

Further information on other theories of asteroid origin and the nature of asteroids can be found in the following recent issues of ASTRONOMY: "Pioneer 10 Finds Asteroid Belt Less Dense Than Thought", page 54, November 1973; "New Theory On How Asteroids Form", pages 53-54, December 1973; "In View of Vesta", pages 38-43, March 1974, and "Safe Crossing of Asteroid Zone", page 44, May 1974. Asteroids are also covered well in the book **Moons and Planets** by W. K. Hartmann (Bogden and Quigley, 1972).

Comment

Suppose we are right — suppose the planet did exist. Shall we propose a name? My first thought was Aztex in recognition of the aerospace expertise at the University of Texas (where I did most of my calculations) and of the Instituto de Astronomia de la Universidad Nacional Autonoma de Mexico (where I did most of the thinking for the subsequent calculations). But my unfamiliarity with popular mythologies soon became apparent when I learned that Superman came from an exploded planet called Krypton. So, in keeping with the tradition of naming the planets from mythology, the lost planet should be named Krypton.

Dr. Michael Ovenden is a professor at the University of British Columbia in the department of geophysics and astronomy. The distribution of the planets and the origin of the asteroids have intrigued him for over 20 years. His most popular book (now out of print) is **Life in the Universe** *(Anchor Books, 1961). He has lectured in many countries and has a distinguished record of published scientific articles.*

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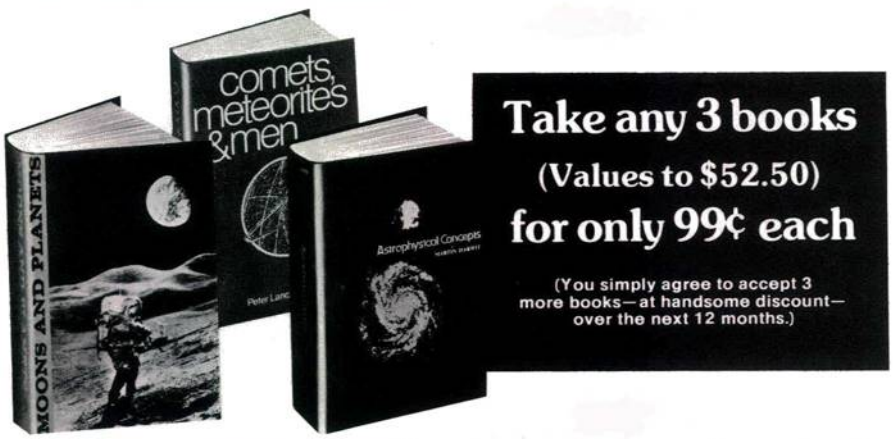
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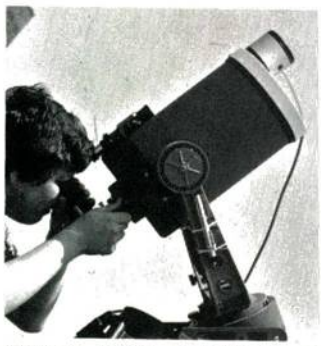

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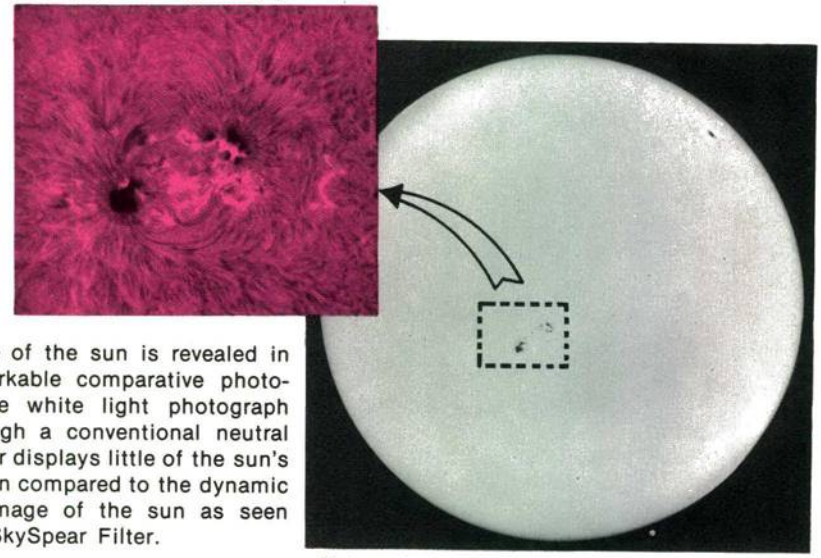

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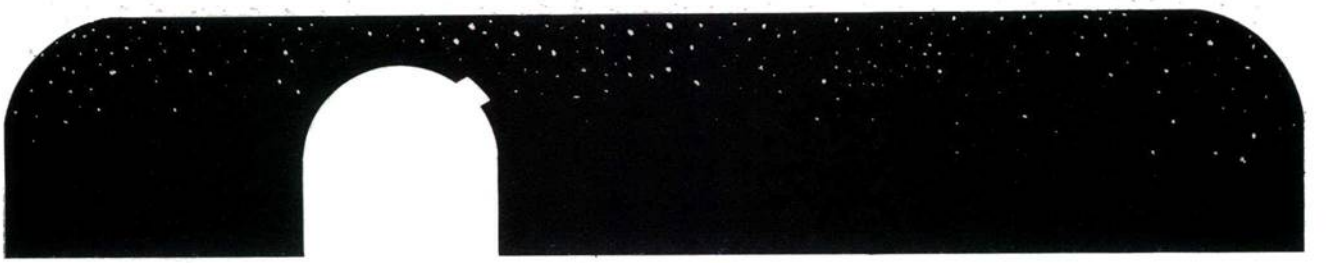

PUBLISHER'S MEMO

Effective with the January 1975 issue, ASTRONOMY will assume a base size of 80 pages! We've promised you this increase for many more months than I care to think about. However, we've learned a lesson in the process: The special 80 page July issue totally derailed our internal editorial schedule and deadlines. That issue was simply too big a load for our editorial staff to handle, and it has threatened late delivery of ASTRONOMY for every issue since. So, as we gear up financially for 80 pages (that's right — we're approaching a circulation of 40,000!), we are starting the search for an assistant editor. Since a qualified editor type may be lurking somewhere out in ASTRONOMY "subscriber-land", we have inserted an announcement below.

Sincerely,

Stephen A. Walther

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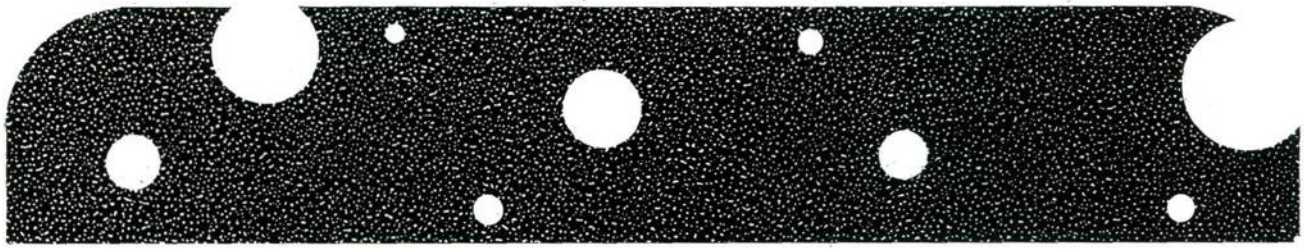


STELLAR FRONTIERS

Inside Gould's Belt

by
Gerrit L. Verschuur

Anyone who has taken a few quiet moments on a clear, dark evening to cast eyes and mind skyward has undoubtedly pondered the meaning of it all: Where did it all come from? Is there an end to the universe? How is it that we are here, on this planet?

As yet there are no answers for these dramatic questions, but smaller pieces of the giant cosmic jigsaw puzzle are beginning to fall into place. We believe we can answer such questions as: Where do stars come from? Why are some parts of the sky filled with bright stars while other regions are almost barren? Actually these two questions are linked in a fascinating way.

Stars are born in unimaginably huge clouds of gas and dust called nebulae. (The sun was born in a nebula about five billion years ago.) Stars are not created alone — usually hundreds or thousands emerge from a single nebula. The Lagoon nebula is just such a stellar maternity ward. As a result of these multiple "births", we often see groups of stars still bunched up. These groups are called clusters.

There are several types of clusters in the Milky Way galaxy; the largest are globular clusters. These colossal balls of up to a million stars contain old stars which have remained as a tight family unit because the total mass of the stars in the cluster is large enough to prevent its members from wandering off into space.

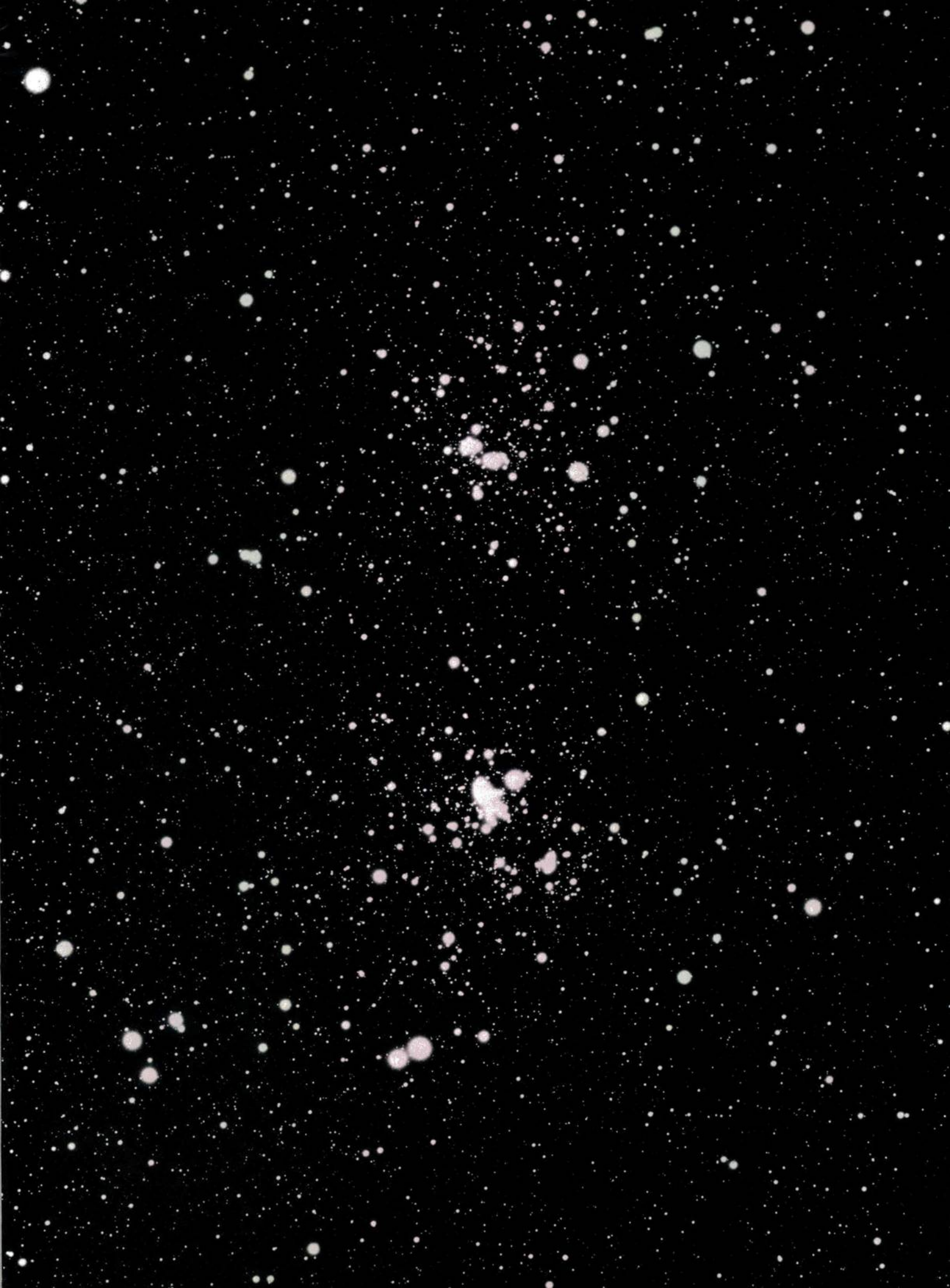
Far smaller and less dense than the globulars are the open clusters (sometimes called galactic clusters). These star groups are usually somewhat younger and the members are more dispersed than a typical globular. The result is a sprinkling of stars that show no concentration toward a definite center, nor are they spherical in shape. Some of the better known open clusters are the Pleiades and the Hyades in the constellation Taurus.

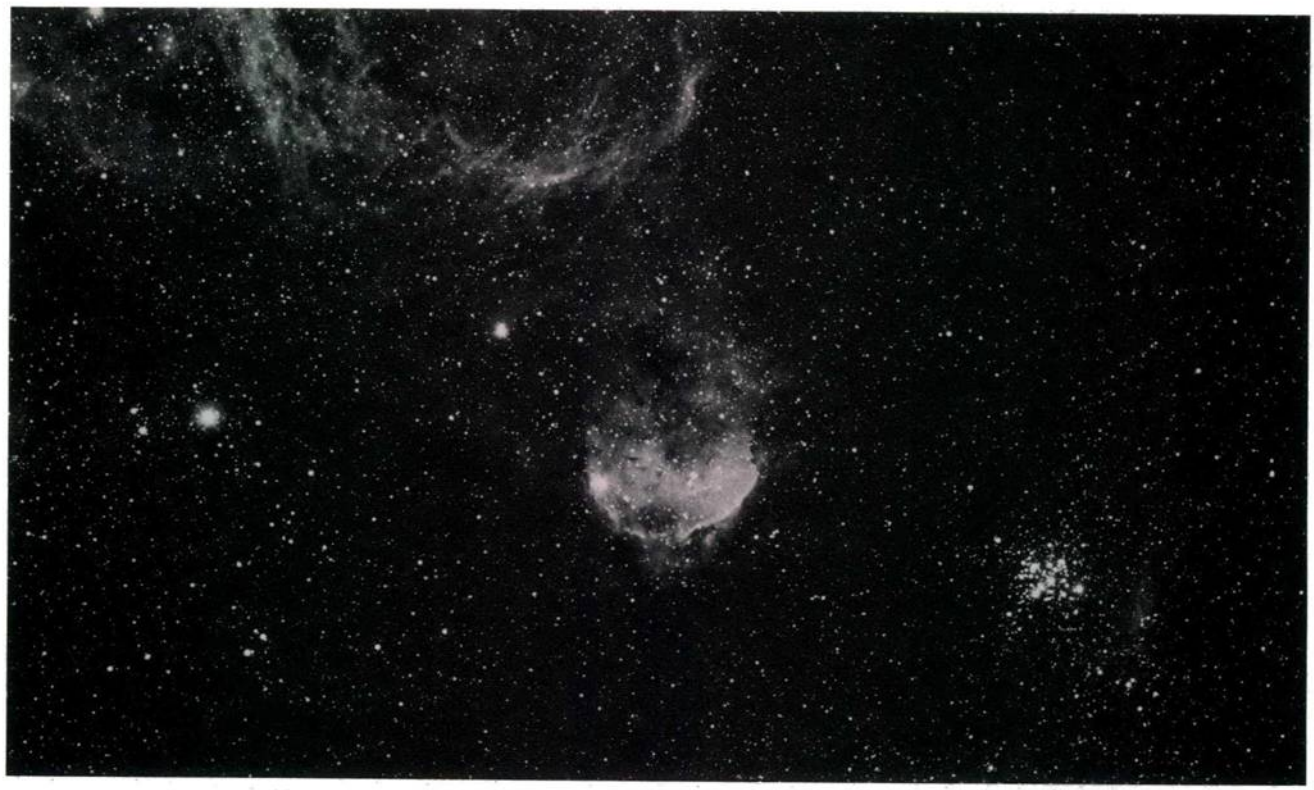
The stars found in open clusters are like those found in the disk of the Milky Way where we are located. Open clusters are composed of younger stars known as Population I stars while globular clusters are comprised of stars (Population II) that are found away from our part of the Milky Way in the so-called halo of our galaxy.

Much smaller than all of these are the associations — loose groups of stars containing young, and usually rather few (50 to several hundred) stars. These stars are mostly hot, blue stars, and the fact that they belong to an association is often hard to recognize. Like open clusters they are found in our part of the galaxy. Association stars were born in a common cloud, but their motions at birth were such that they rapidly moved away from their point of creation over the next few million years. This means that they are spread out over large areas of the sky and astronomers have to measure their motions through space and extrapolate backward to recognize the fact that they are actually parts of associations. This is not true of all associations though, since

The double cluster in the constellation Perseus is believed to have formed from a titanic cloud of dust and gas less than 10 million years ago, about the same time many of the stars in Gould's belt were born. Each swarm of stars is about 100 light-years wide — much more compact than Gould's belt. In a few million years these two clusters will become fainter and more diffuse as the bright stars burn out and the remainder stray away into deep space.

Lick Observatory Photograph





Harvard Observatory Photograph

A nebula and an open cluster of stars indicate two stages in the history of stellar evolution. The nebula NGC-3324 (center) is probably going to give birth to a cluster of stars like NGC-3293 (just to its right). The cluster will eventually become unrecognizable as its member stars slowly disperse over the next few million years. Part of the Eta Carinae nebula extends into the upper part of this photo. These objects are only visible south of the Tropic of Cancer.

some distant ones are quite clearly grouped but spread over hundreds of light-years of space.

Since associations are the youngest groups of stars (they have to be young or they would be dispersed), they are often not very far from the clouds in which they were born. The gas and dust in those clouds which was not consumed in the star formation process often gets heated by nearby hot stars and forms an emission nebula such as the Orion nebula. The Orion region is interesting in that the nebula is within an association, and there is a cluster inside the nebula. A hierarchy of star groups can evolve in one general region of space depending probably on the initial structure of the gas cloud.

What happens to the stars in open clusters and associations over a very long time — say many tens or hundreds of millions of years? Of course the largest stars like Rigel would burn themselves out in that time. But other less massive stars like the sun would not, so they continue to move through space farther and farther from their birthplaces. They would then join the majority of stars in the galaxy that have been wandering through space in this way for billions of years.

The sun is just such a common, everyday star. On its wanderings it has probably passed close by and through many clouds of gas and dust in which star formation was only just beginning. One such visit to a dense cloud from which many stars were formed was made as recently as 40 million years ago. The stars that were born in that cloud only 10 million years ago now make up a belt of bright naked eye stars that cuts across the Milky Way (known as Gould's belt).

If you examine the sky on a clear winter evening (or after midnight this month) you will notice that the brightest stars — such as those in Orion, Taurus and Canis Major — are to one side of the Milky Way. On a summer night we would see that the bright stars in Lyra and Scorpius also lie off the Milky Way. (Those southern hemisphere dwellers lucky enough to see the bright constellations Carina, Crux and Centaurus notice the effect even more.)

Yet we know the hazy band of light, the Milky Way, is due to our view into the disk of our galaxy from some vantage point within that disk. So why are most of the bright stars not embedded in the Milky Way? The effect is so striking that on a very clear night in the southern hemisphere, one gets the impression that there is another band made up of the very bright stars which protrudes from the Milky Way itself.

This phenomenon was first reported by Sir John Herschel in 1847, but the first astronomer who described it carefully was B. A. Gould in 1879 (hence its name). It has been said that Sir Francis Drake was also struck by this band of stars during his cruises in the southern hemisphere.

What is Gould's belt and why are the bright stars arranged in this pattern? Much work has been done recently on trying to explain this. Astronomers have found that not only isolated stars are members, but several clusters and associations are also part of it. These include the Scorpio-Centaurus association; the Orion association (including the Orion nebula), and possibly the Pleiades.

Basically we can describe Gould's belt as the local group of stars (mostly B type stars) mainly consisting of clusters and associations which are now beginning to move apart. We on Earth, orbiting our older G type star, find ourselves very nearly in the middle of this group of stars — but we are only here by chance!

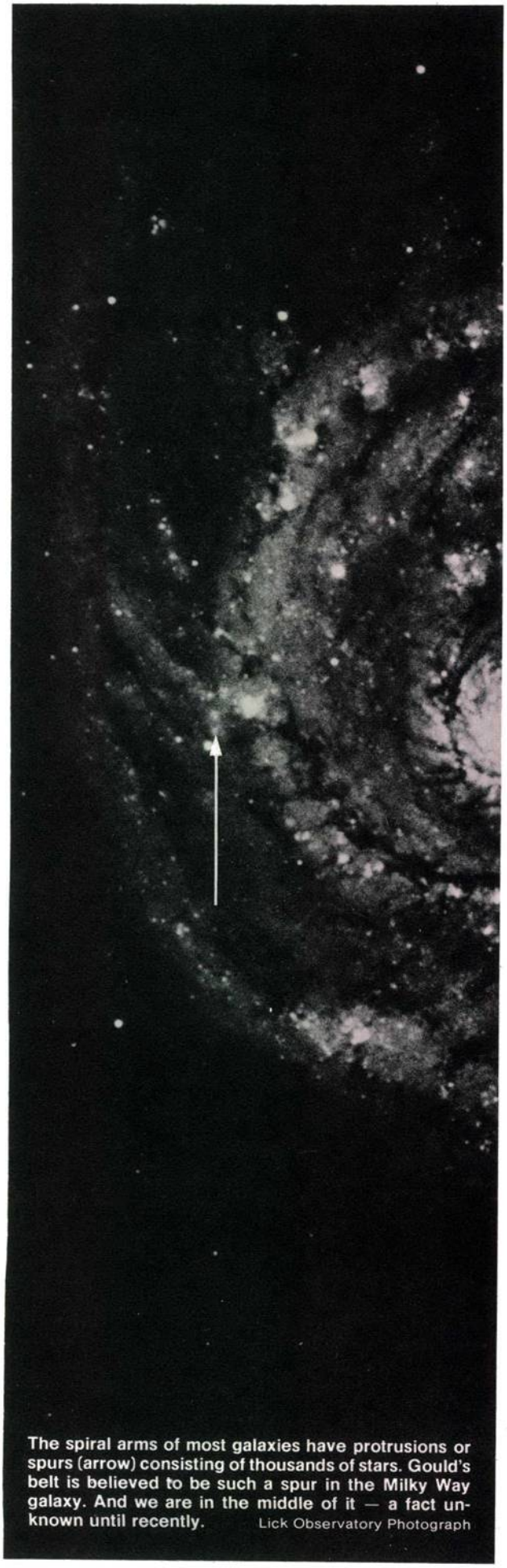
By studying the present motions of the stars in the belt and extrapolating backward, we have found that Gould's belt had a common point of origin about 40 million years ago. At that time a giant gas and dust cloud was just reaching conditions which made it ripe for star birth to start. Most of the stars in the belt are about 10 million years old, so the cloud actually spawned the stars at that time.

Where was the sun during all this? Well it was probably right there in the cloud that created Gould's belt. If that was so, the skies would have looked very different then — since all the stars that make up the belt would have been much closer together. The sky was probably full of first magnitude stars. It is possible that some of those B stars might have had emission nebulae associated with them early in their lives. So we speculate as to what splendors might have been visible — perhaps even to the naked eye — from our planet only 5 to 10 million years ago.

And what about the future? As we mentioned, the present motions of the stars in Gould's belt show that they all had a common origin — a single large cloud — some 40 million years ago. That means that the cloud started to expand outward at that time, although star formation didn't occur for another 30 million years. The stars of

Photograph by Patrick Michaud

The Pleiades, the brightest star cluster in the sky, is believed to be part of Gould's belt. This dipper shaped compact group of young blue stars can be seen low in the east on October evenings. The hazy nebulosity — left over from the recent birth of these stars and illuminated by them — is too faint to be seen visually.



The spiral arms of most galaxies have protrusions or spurs (arrow) consisting of thousands of stars. Gould's belt is believed to be such a spur in the Milky Way galaxy. And we are in the middle of it — a fact unknown until recently. Lick Observatory Photograph

Gould's belt have retained this motion and in another 10 million years the night sky will no longer look anything like it does now. Many of the belt stars will have strayed much farther away while others — the brightest ones — will exhaust their supply of nuclear fuel and die.

At the present time Gould's belt is about 2,000 light-years wide, 600 light-years thick, and is tilted at 20 degrees to the Milky Way. This implies that the initial cloud was spinning, 40 million years ago, so that the present disklike configuration could result.

In trying to picture just where the belt is located, remember that Orion is part of it and the nebula in the sword of Orion is about 20 degrees from the Milky Way. That is one of two places where Gould's belt reaches its greatest distance from the Milky Way. On the opposite side of the sky it diverges 20 degrees the other way, not far from Antares.

Now let's see what our new data about Gould's belt tells us about our place in the galaxy as a whole. We believe that our galaxy is a spiral galaxy of some sort, which means that the stars, gas and dust in the disk are loosely organized into spiral-like structures. It was thought for a long time that perhaps that sun was inside a spiral arm, or at the very least on the edge of a spiral arm. However it now appears more likely that we are in a spurlike structure that protrudes from a spiral arm — a spur that is basically Gould's belt.

Such spurs or wisps between and protruding from spiral arms are seen in profusion in photographs of other spiral galaxies — very few of which really show a symmetrical spiral pattern (see photo, opposite). Gould's belt is therefore a substructure linked to a spiral arm, but it is not an integral part of a spiral arm.

The sun is moving at a slow pace — about 13 miles per second through the surrounding stars and gas in the local group of stars. At that speed we move 60 light-years in a million years, or 6,000 light-years in a hundred million years — the time since the dinosaurs last stalked this planet. And that figure refers to motion through the stars near us — and not to our motion around the center of the Milky Way which is a steady 150 miles per second. (This motion has sent us completely around the giant wheel that is our galaxy during the last 100 million years.)

The chances are fairly good that we will frequently stray in and out of clouds of gas that are about to form stars or are actually forming stars because those clouds are in turn moving around fairly randomly. So finding ourselves inside Gould's belt is not too surprising. And who knows where else our sun and planets have been, and what splendors the creatures on Earth have perceived in the skies in eons past.

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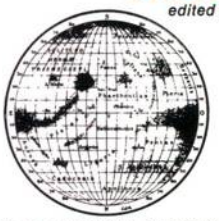

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"Which Color Film Should I Use?"

by
Leo C. Henzl Jr.

This is probably the most common question asked by the beginning astrophotographer, and it's a question that has different answers depending on what you want to try to shoot.

There are a dozen or so commonly available color slide films. If your budget allows for only one reasonably good camera (as is the case with most of us), you might well say, "I'll probably end up using whatever happens to be in my camera."

Unscientific as this might seem, a color slide film suitable for standard outdoor photography of people and scenery is often the same film you should choose for astrophotography. None of the current slide films was really designed for the purposes of the astrophotographer; only because the parameters of ordinary "snapshooting" and astrophotography overlap at some points can we use transparency films at all for celestial subjects. (As a general rule, color slide films are preferable to color print films for astrophotography.)

These two five minute exposures taken under identical conditions with 50mm f/2.0 lenses vividly reveal the differences between two color transparency films — both of which are suitable for a variety of astrophotographic tasks. Fujichrome R-100 (top) records somewhat more detail than the High Speed Ektachrome but at some minor loss in color fidelity and a less natural appearing sky background. Both produce slides suitable for large blowups or magazine reproduction. This same area is shown in more detail on page 60 of last month's issue.

Photographs by Leo C. Henzl Jr.

The moon, for example — being the same average distance from the sun as Earth — receives the same amount of illumination per unit of surface area, and thus requires about the same exposure as a similarly lit earthbound subject. If the film you're using calls for 1/60 second at f/8 with a front-lit subject here on Earth, the same combination should also produce a satisfactorily exposed slide of the full moon which is also a front-lit subject. So it's likely that the medium speed transparency film you've selected for its pleasing rendition of flesh tones in photos of bathing beauties will also yield acceptable lunar slides, simply because the illumination levels are similar and well within the recording capabilities of the film.

Within the range of light levels encountered in daytime photography, you can count on your film to respond in a predictable fashion. In the instance mentioned above, you could employ all the following combinations of shutter speeds and lens openings to achieve virtually the same final result as 1/60 second at f/8:

Lens opening	Shutter speed
f/1.4	1/2000
f/2.0	1/1000
f/2.8	1/500
f/4.0	1/250
f/5.6	1/125
f/8	1/60
f/11	1/30
f/16	1/15

This table is an illustration of a film property known as the reciprocal rule of equivalent exposures. All this term means is that the film responds in the same manner to conditions of high light intensity and short duration of exposure (f/1.4 at 1/2000 second) as it does under conditions of lower intensity and longer duration (f/16 at 1/15 second). All the total exposures in the sequence are equivalent, because exposure duration is doubled in each successive case to compensate for the progressive reduction in light intensity. Similarly, if you jump two f/stops in the table, thereby reducing intensity to 1/4 its previous value, you must increase the exposure duration by a factor of four to effect the same total exposure. Hence, for a subject of normal brightness, shutter speed increments and f-ratios are reciprocally interchangeable.

This relationship holds true so long as the intensity of light reaching the film remains above a given value, somewhat different for each film. All films, however, require a certain intensity of light to "get started" before they will respond in the linear manner described. Below this light value, films begin to require an exposure duration disproportionately longer than calculation might suggest to obtain the desired result. This peculiar behavior is known as reciprocity failure and is something like the need for priming a water pump. Unless the pump has sufficient fluid to sustain a healthy siphon action, no amount of muscular action will yield much more than a trickle of water.

With most slide films, reciprocity failure usually begins when the light intensity is low enough to require an exposure time approaching one second. Generally photography of planets or constellations requires exposure times of at least a few seconds, so we are already encountering reciprocity failure. Here, however, we are dealing with light levels not too drastically different from those of so-called "available light" photography. Again, your old standby film of medium speed will probably render acceptable, if not commendable, results in these realms of astrophotography.

What happens, though, when that same film is called upon to record light levels several thousand times dimmer than were ever its designers' intent? Light levels, that is, such as we encounter in guided photography of really dim subjects like faint stars, diffuse nebulae and the distant galaxies? Eventually if intensity of light at the film plane is sufficiently low, the film will simply fail to respond at all — no matter how long the exposure. This point of total failure is called the film's threshold response level. Fortunately many of the common deep sky wonders we might wish to photograph are bright enough to be above this level at the film plane of typical amateur instruments. The aperture and/or f-ratio of your camera or camera/telescope combination will determine how much light is delivered to the film for a particular deep sky subject. Since recording extended objects depends wholly on f-ratio, nebulae below threshold for your f/5.6 telephoto lens may be recorded brilliantly with an f/1.5 Schmidt camera. Similarly, with point-source objects — like the individual stars in a galactic cluster where an optical system's recording power is almost wholly aperture dependent — the stellar images a 10 inch reflector will record in minutes might be beyond the reach of a one hour exposure through a two inch refractor.

How can we predict the response of a particular film to the extremely low light levels of long exposure photography? The task is fairly simple with black and white films, as most manufacturers publish reliable reciprocity data. With color films, however, the situation is complicated by

the fact that three separate emulsion layers — one sensitive to red light, one to green, and one to blue — are required to produce the full range of colors. Since the three layers may (and usually do) exhibit differing rates of reciprocity failure, we also have to contend with the possibility of color imbalances. If, for instance, a film's red layer fails more rapidly than its green, the excess of green dye in the final slide will shift the sky background color in this direction.

What about film speed? Common sense suggests that faster films should be superior, but under extremely low light levels this isn't always the case. Reciprocity testing under actual shooting conditions seems to be the only way to properly evaluate color transparency films for long exposure astrophotography. For evaluation of this kind to be meaningful, however, it is vital that all slide films be shot under comparable conditions. A seemingly trivial difference in atmospheric transparency between testing of two films could drastically alter, or even reverse, the results.

Assembling the necessary equipment and personnel for simultaneously testing all the slide films with sufficient speed to be potentially useful for deep sky photography is quite a task. But we did manage to successfully compare the eight commonly available color slide films with ASA indices of 64 or greater. Slower films were excluded because no matter how good a film of lesser speed might be from the standpoint of reciprocity failure, it would probably still be too slow for use in guided photography.

The color slide films selected for testing were: Kodak Kodachrome 64, Kodak Ektachrome-X, GAF 64, Agfachrome 64, Fujichrome R-100, Kodak High Speed Ektachrome, GAF 200, and GAF 500.

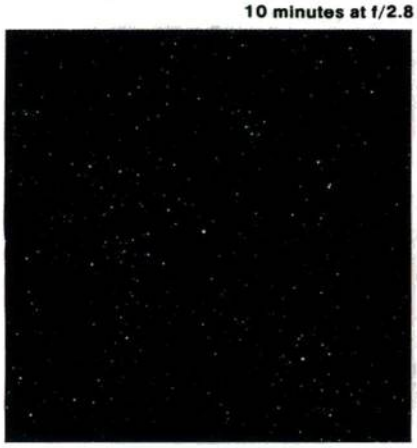
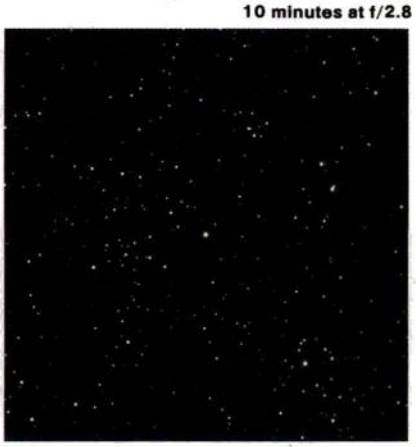
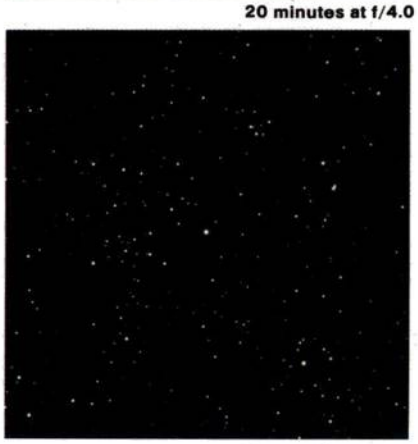
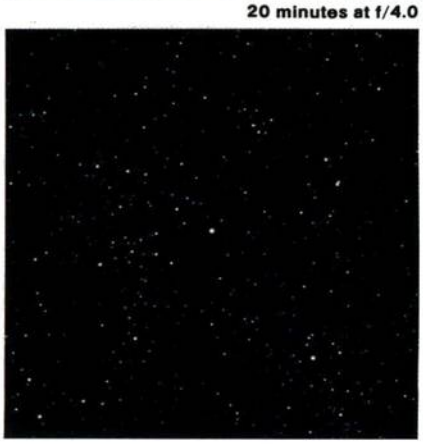
All were loaded into name brand 35mm single lens reflex cameras, equipped with 50mm "normal" lenses of proven quality. When that rare night of nearly perfect transparency finally materialized, the cameras were mounted piggyback on commercially made Schmidt-Cassegrain telescopes equipped to carry multiple cameras. The cameras were centered on the star Deneb in the constellation Cygnus — an area rich in Milky Way background, star clusters and extended nebulosity. Each film was exposed with careful guiding at high magnification as follows: 5 minutes at f/2.0; 10 minutes at f/2.8; 20 minutes at f/4.0, and 40 minutes at f/5.6.

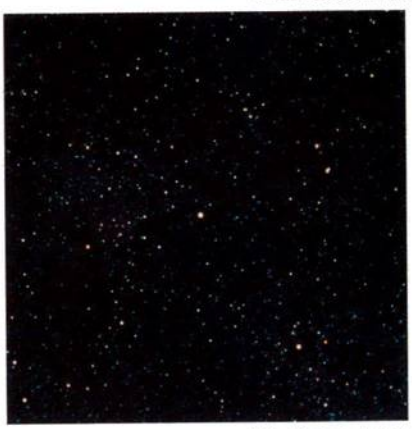
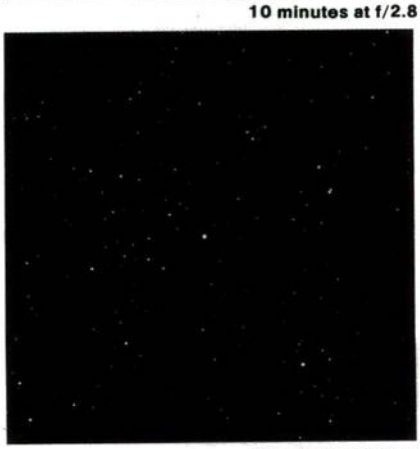
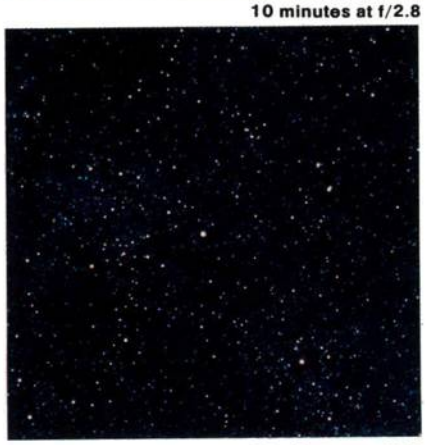
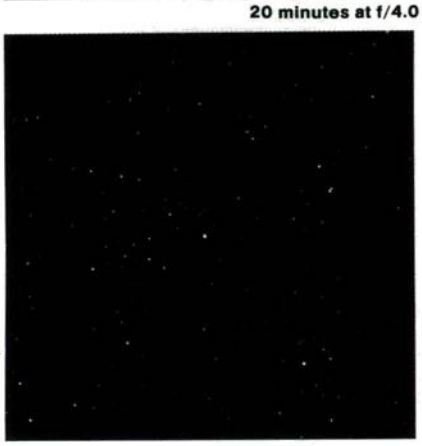
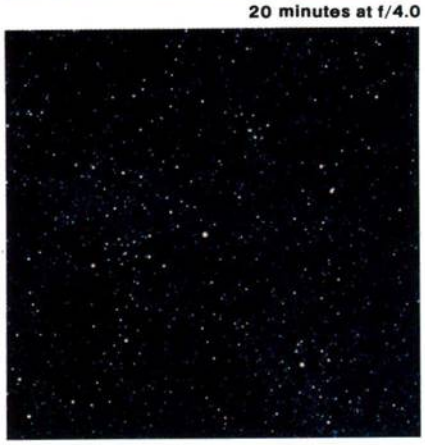
Sky conditions were monitored for comparability throughout the test; all proceeded smoothly

LONG EXPOSURE ASTROPHOTOGRAPHY: HOW THE FILMS PERFORMED

	Kodachrome 64	Agfachrome 64	Fujichrome R-100	High Speed Ektachrome	GAF 200	GAF 500
Recording power (ability to record faint objects)	6	5	3	4	2	1
Lack of grain	1	2	3	4	5	6
Sky background density	1	2	5	3	6	4
Color differentiation and brilliance of colors	5	2	3	1	6	4
Contrast (brilliance of images compared to sky background)	1	2	5	3	6	4

Usually several factors influence the choice of film for long exposure astrophotography. No film does well in all categories listed in the table. Select the film that performs best in the function most important to your particular photographic project. Films were ranked in order in each category, from a highest rating of 1 to a lowest rating of 6. For example, Kodachrome 64 yields the darkest sky background while GAF 200 gives the palest background among the films. Yet we find Kodachrome 64 records the least number of stars and GAF 500 captures the most. Films were rated by the author and a panel of critics using the photos reproduced on pages 26 and 27.

Kodachrome 64	Agfachrome 64	Fujichrome R-100
5 minutes at f/2.0	5 minutes at f/2.0	5 minutes at f/2.0
10 minutes at f/2.8	10 minutes at f/2.8	10 minutes at f/2.8
		
20 minutes at f/4.0	20 minutes at f/4.0	20 minutes at f/4.0
		
40 minutes at f/5.6	40 minutes at f/5.6	40 minutes at f/5.6

High Speed Ektachrome	GAF 200	GAF 500
5 minutes at f/2.0	5 minutes at f/2.0	5 minutes at f/2.0
		
10 minutes at f/2.8	10 minutes at f/2.8	10 minutes at f/2.8
		
20 minutes at f/4.0	20 minutes at f/4.0	20 minutes at f/4.0
		
40 minutes at f/5.6	40 minutes at f/5.6	40 minutes at f/5.6

Photographs by Leo C. Henzl Jr. and David A. Potter

except for a visiting satellite recorded in several frames. The films were then sent to their original manufacturers for processing at normal ASA ratings. (This is an important point for readers who might wish to attempt their own testing.)

Since each of the time and intensity combinations employed will deliver an equal amount of exposure to the film plane (following the reciprocal rule of equivalent exposure mentioned earlier), we would expect similar final results for all exposures on a particular film — if the film was responding in a reciprocal manner. As the accompanying color spread will show, all films failed to some extent with decreasing light intensity. Two of the films, Ektachrome-X and GAF 64, exhibited exceptionally severe reciprocity failure and color shift, and are thus not reproduced here as they would probably prove unsatisfactory for guided deep sky photography. This, of course, is no reflection on the capabilities of these films for normal "snapshooting" or for lunar and planetary work — the light levels for which they were designed — as both enjoy wide acceptance among photographers. (We also encountered minor problems in using ordinary camera optics for a purpose outside their designers' intent: All were beset with edge-of-field aberrations at apertures numerically less than f/4.0, so only the central portions of the 35mm frames are reproduced here.)

Each of the six remaining slide films excelled in one respect or another, though none exhibited every desirable quality we might wish for in long exposure photography. The progressive deterioration in recording power and color balance with decreasing light intensity, when compared to the shortest exposure at f/2.0, is an indication of a film's reciprocity characteristic. In this respect, the ultrafast GAF 500 was exceptional. But if we compare the nearly identical recording power of High Speed Ektachrome (ASA 160) with that of Fujichrome (ASA 100), we see that the performance is not as disparate as the ASA indices would indicate.

A few film properties other than sheer recording power can also be assessed from examining the color reproductions. Some films, for example, did a better job than others of differentiating among stars of different colors — with High Speed Ektachrome being the champion in this respect. In slide projection, this film was also judged to render the most neutrally colored sky background. Superior contrast was evident in the Agfachrome 64 and Kodachrome 64, so that the projected slides seemed subjectively sharper than with the other films.

As might be expected, the high speed films exhibited considerably more grain than the slow — although even the very fast GAF films were judged satisfactory for slide showing at normal room distances. For other purposes, such as color enlargements of appreciable size or photos for publication, one would do well to consider the slower films.

To examine granularity, as well as general imaging characteristics, we used a microscope to examine the central portions of each film frame shot at f/5.6, at which point optical aberrations were minimal with all the lenses used. As a comparison reference for the various films, High Speed Ektachrome was judged the fastest film capable of yielding an 8 x 10 inch enlargement from the full frame without objectionable grain. The two GAF films were very similar on grain structure, so from this standpoint we could see little advantage in using GAF 200 in preference to GAF 500 for deep sky photography — especially in view of the latter's superior color rendition and recording power. Kodachrome 64 appeared the least grainy of all and, assuming optics equal to the task, should be capable of enlargements to 11 x 14 inches or greater. Fujichrome R-100 also deserves special mention, as it displayed a favorable combination of recording power and relatively fine grain. Its tendency to shift toward the green at low light levels could be rectified with the proper filtration in color printing, as could most of the various color imbalances of the other films. (Such rectification was not used in any of the reproductions in this article.)

Inasmuch as the test was conducted under a given set of circumstances, we would hesitate to label the test results as conclusive for all possible long exposure situations. It is likely that readers shooting under conditions either more or less favorable than ours here in the Midwest will experience somewhat different results with respect to the absolute properties of particular films. We would expect, however, the relative performance of various emulsions to be consistent over a wide range of exposure conditions.

To return to our original question of a "best" film, we won't attempt to single out one on the basis of this test as the results are largely specific to a single area of astrophotographic endeavor. If, however, long exposure color astrophotography is on your present or future agenda, you'll want to keep the results in mind the next time you visit your film dealer. Even if not, one of these films might be just the ticket for shooting bikini clad beauties by starlight!

Leo Henzl is the Midwest technical sales representative for Celestron Pacific and Carson Astronomical Instruments, and devotes full time to astronomy and astrophotography — his lifelong interests. Before moving to his present home in Sandwich, Ill., he spent three years on Eastman Kodak's editorial staff in Rochester, N.Y. He is astrophotographic director of the Sandwich Astronomical Society, whose members assisted in the film test described in this article.

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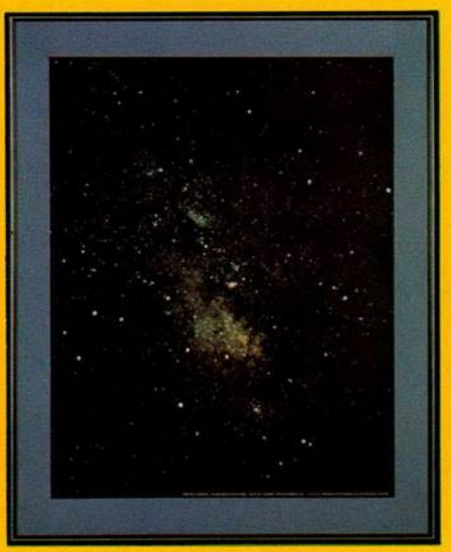

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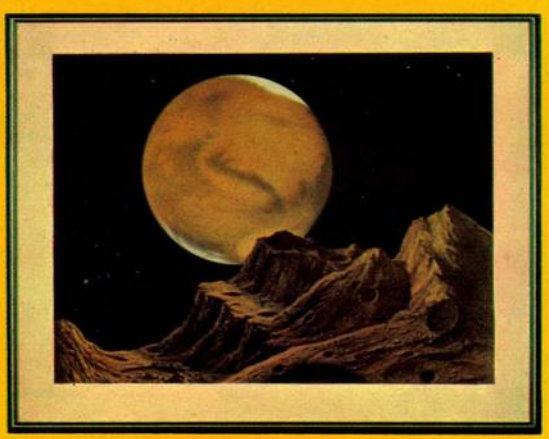

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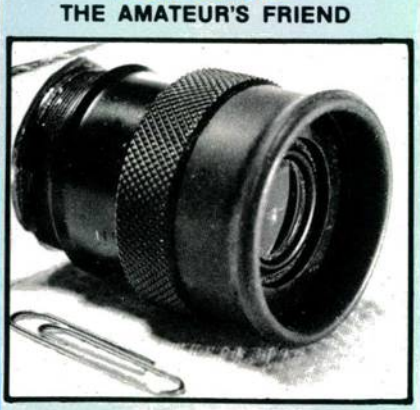

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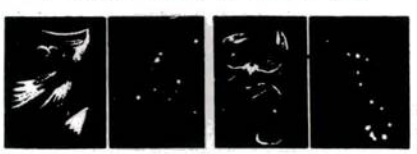

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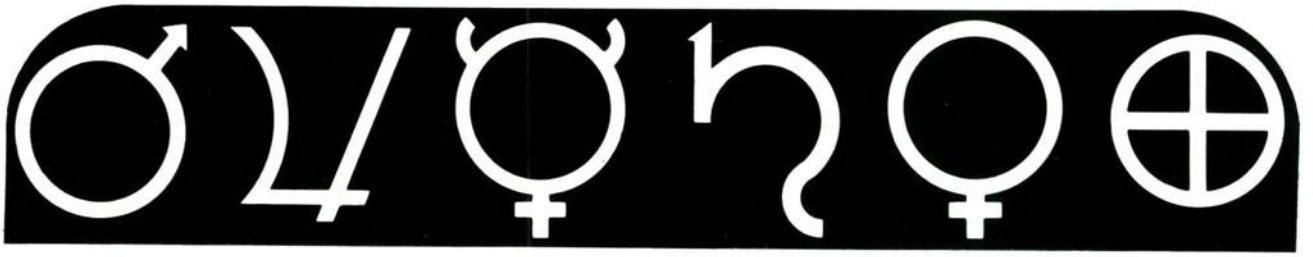
INFORMATION WANTED — Dates and names of comet flare-ups. Example: Tuttle-Giacobini-Kresak, July 8, 1973. Send to Harald Schenk, 2330 S. 11th St., Sheboygan, WI 53081.



SKY ALMANAC

Jupiter, Saturn and Meteors in October

Jupiter continues to dominate the southeastern sky as it did last month — but the only other planet visible is Saturn, and you have to wait till after midnight for it. A moderate meteor shower later in the month helps to round out the early autumn sky.

Jupiter

Although the giant planet was slightly closer last month, we still have an excellent view of it so it remains our first choice for observation.

To the unaided eye, Jupiter is superbright at magnitude -2.4 early in the month, dropping slightly to -2.2 by early November. Look for it in the southeast as soon as it gets dark. There's no mistaking Jupiter — it's brighter than anything now in the night sky apart from the moon. Most people say Jupiter looks white or slightly yellow-white; what color do you perceive?

An interesting naked eye experiment is to "place" Jupiter at the top of a chimney or telephone pole. Simply walk around until your line

The most intense auroral display in at least a year lit up the sky over much of the country at about 1 a.m. July 6, 1974. At its most intense period the flickering arcs filled over 70 percent of the sky. Lower photo is a 30 second exposure on High Speed Ektachrome pushed to ASA 400; a 50mm f/1.4 lens was used wide open. Top photo is a 10 second exposure with similar equipment on Agfachrome 64. The double star at the bottom edge of the auroral curtain is Mizar.

Photograph by Diane L. Payton

Photograph by Thomas C. Bretl

Photographs by Michael Good

From the extreme southwest tip of Australia these views of the June 20, 1974 total eclipse of the sun were captured by two lucky eclipse chasers who were not clouded out. A few solar prominences can be seen peeking between the moon's mountains in the far left photo. This and the center picture were taken through a Vivitar 400mm lens at 1/125 and 1/15 second respectively, on Kodachrome 64 film. Photo at right, showing the "diamond ring" effect through light clouds, was a 1/250 second exposure on Kodachrome 25 through a three inch refractor.

of sight puts Jupiter there, mark the spot, and return an hour later. Jupiter (and the stars around it) will be shifted west by a noticeable amount. Earth's rotation, of course, is responsible for this westward motion, and Jupiter is a good object to use to demonstrate the effect.

The moons of Jupiter are among the most fascinating of all the sights in the sky. They can easily be seen with even the crudest telescope but their antics, such as the shadows they cast on their parent planet's cloudy surface, are somewhat harder to observe. Robert Midiri of Philadelphia, Pa. recently wrote to tell us about his surveillance of three of the four bright moons:

"I observed with interest the recent shadow transits of Europa (Aug. 2, 1974), Io (July 21 and Aug. 13), and Callisto (Aug. 9). On Aug. 2 I observed Europa's shadow through a six inch reflector at 240x. Even though it was on a dark belt, the shadow stood out fairly well once it moved in from the edge. It was a hazy night with fair seeing. The shadow seemed smaller and not as dark as Io's. I couldn't see the shadow at 60x in the six inch and it was not observable with my 2.4 inch refractor at 120x. Callisto's shadow was clearly visible on a bright zone of Jupiter on Aug. 9-10. The shadow was darker than Europa's and easily seen at 60x. I searched, and knowing exactly where to look, found it using averted vision with the 2.4 inch refractor at 120x although it was difficult to see. To me, Europa's shadow seems the hardest of the four to observe. On Aug. 13-14 I followed Io's disk as well as its shadow with the six inch at 240x on the face of Jupiter."

Our reader mentions seeing the satellite Io in front of Jupiter. The satellites, themselves, are much harder to see than their shadows because they are often over clouds of matching colors. We include only the shadow predictions here each month because they are the easiest and most

SATELLITE SHADOWS ON JUPITER

Date	Satellite	Transit begins (EDT)	Transit ends (EDT)
Sept.30-Oct.1	3	11:35 p.m.	2:57 a.m.
Oct. 4-5	2	11:27 p.m.	2:14 a.m.
6	1	1:23 a.m.	3:40 a.m.
7	1	7:52 p.m.	10:09 p.m.
11	2	2:03 a.m.	4:49 a.m.
13	1	3:19 a.m.	5:35 a.m.
14-15	1	9:48 p.m.	12:04 a.m.
16	4	12:30 a.m.	3:47 a.m.
21-22	1	11:44 p.m.	2:00 a.m.
22	2	5:57 p.m.	8:42 p.m.
29	1	1:39 a.m.	3:55 a.m.
29	3	3:43 p.m.	7:01 p.m.
29	2	8:33 p.m.	11:18 p.m.
30	1	8:08 p.m.	10:24 p.m.
Nov. 1	4	6:52 p.m.	9:57 p.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

Photograph by Stephen Schiller

dramatic satellite phenomena to observe.

Jupiter itself is as colorful as ever this season with the Red Spot a distinct pink hue. Can the spot be clearly seen in a 2.4 inch refractor?

During October the giant planet recedes from Earth increasing its distance from 379 million miles on the 1st to 410 million miles by the 31st. The planet's equatorial diameter shrinks correspondingly from 48.2 seconds of arc to 44.7 seconds during the month. The polar diameter is always seven percent less than these figures.

Saturn

Shortly after midnight, especially later in the month, a brilliant zero magnitude "star" rises just north of the east point. The "star" is actually Saturn, and a quick glance through your telescope will confirm it. Any telescope that magnifies 30 times or more should show the rings — now wide open to our view.

As you look in the eastern sky for Saturn you may confuse it with the star Capella in the constellation Auriga. Capella is about the same color and brightness as Saturn but it's higher above the horizon. If what you are looking at is twinkling, it's probably Capella. Saturn (like all planets) does not twinkle except at times of unusual atmospheric turbulence.

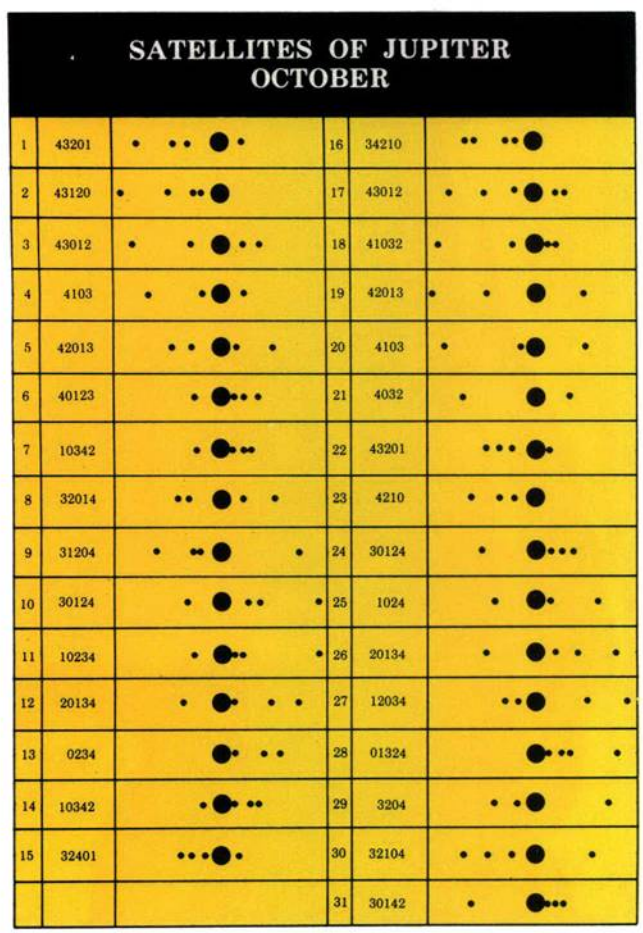
Earth pulls closer to Saturn during October — the distance between the two worlds diminishes from 849 million to 804 million miles. This causes a barely perceptible increase in brightness from magnitude+0.3 on the 1st to+0.2 at month's end. The apparent width of the rings swells from 41.1 seconds of arc on the 1st to 43.4 seconds by the 31st, while the globe of Saturn increases correspondingly from 18.2 seconds of arc to 19.3 seconds in equatorial diameter.

Mercury, Venus, Mars, Uranus, Neptune, Pluto

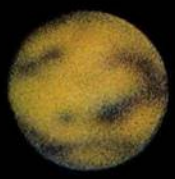
There are eight other worlds that orbit the sun along with Earth. This month six of them happen to be clustered so that they appear in the same region of the sky as the sun and are therefore not visible. You can find all of them plotted on the chart on pages 36 and 37 near the stippled zone.

Perseid Meteors Observed

The Perseid meteor shower in August produced a deluge of mail at ASTRONOMY. The corres-



The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 10 p.m. (EDT) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto, and 0 = Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.



Ⓒ Ceres

Oct.	1	15
R.A.	22h40m	22h33m
Dec.	-24°30'	-24°09'
Mag.	+7.4	+7.5

Ⓐ Mercury

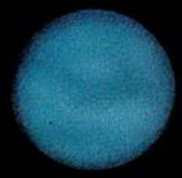
Oct.	1
R.A.	14h03m
Dec.	-15°36'
Dia.	6.8"
Mag.	+0.3

Ⓑ Mercury

Oct.	15
R.A.	14h27m
Dec.	-17°56'
Dia.	9.0"
Mag.	+1.0

Ⓜ Mars

Oct.	1	15
R.A.	12h47m	13h21m
Dec.	-4°21'	-7°59'
Dia.	3.6"	3.6"
Mag.	+1.9	+1.8

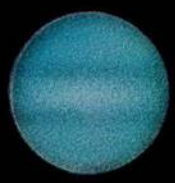


SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Oct.	1	15
R.A.	7h18m	7h21m
Dec.	+21°44'	+21°39'
Dia.	18.2"	18.7"
Mag.	+0.3	+0.3

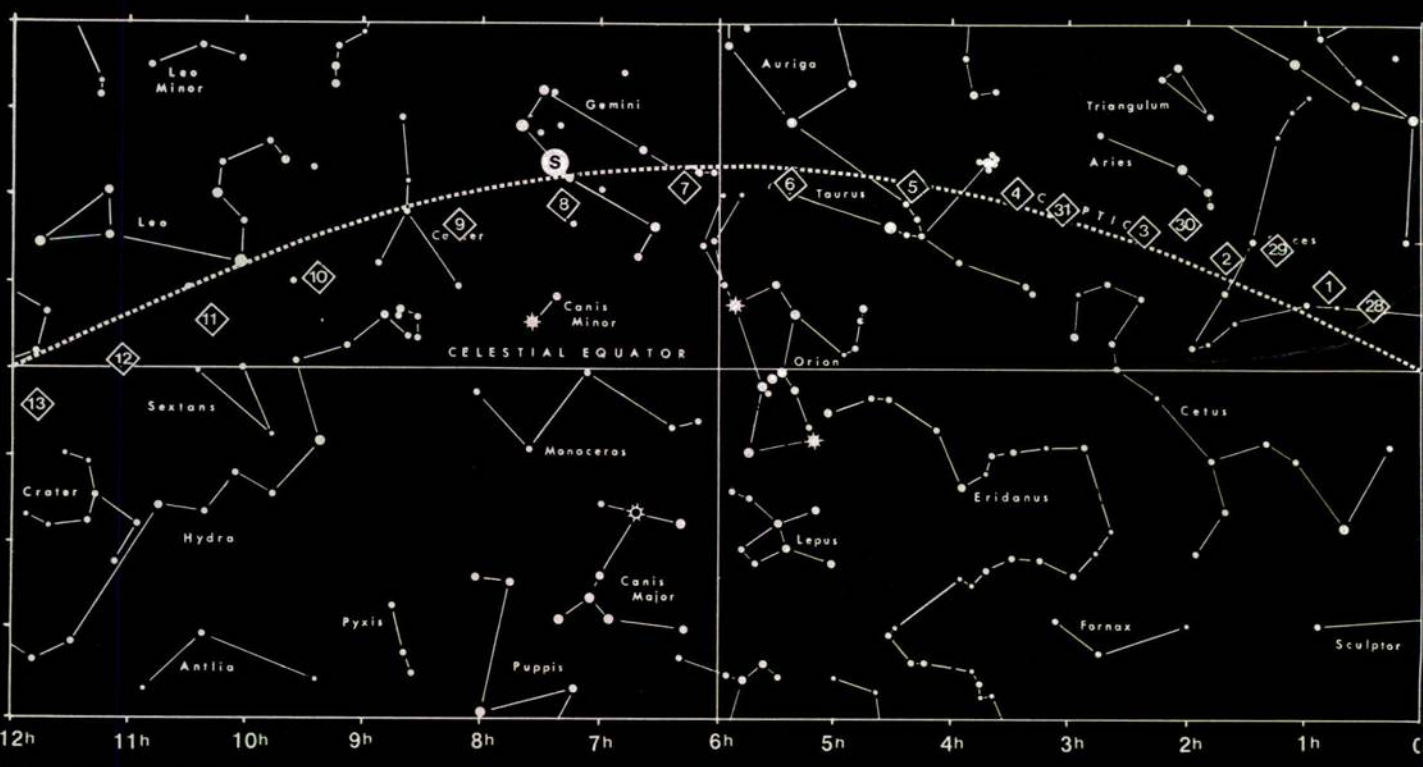


Ⓤ Uranus

Oct.	15
R.A.	13h44m
Dec.	-10°05'
Dia.	3.5"
Mag.	+5.8

Ⓝ Neptune

Oct.	15
R.A.	16h25m
Dec.	-20°05'
Dia.	2.4"
Mag.	+7.7



Map by Raymond G. Coutchie

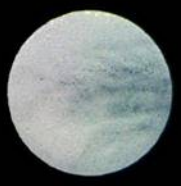
The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. **R.A.** = right ascension and **Dec.**. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. **Mag.**. = magnitude, a

Ⓥ Vesta

Oct.	1	15
R.A.	15h15m	15h43m
Dec.	-14°46'	-16°57'
Mag.	+7.5	+7.6

Ⓙ Jupiter

Oct.	1	15
R.A.	22h47m	22h43m
Dec.	-9°16'	-9°40'
Dia.	48.2"	46.8"
Mag.	-2.4	-2.3



Ⓨ Venus

Oct.	1
R.A.	12h00m
Dec.	+1°37'
Dia.	10.0"
Mag.	-3.4

Ⓩ Venus

Oct.	15
R.A.	13h04m
Dec.	-5°21'
Dia.	9.9"
Mag.	-3.5

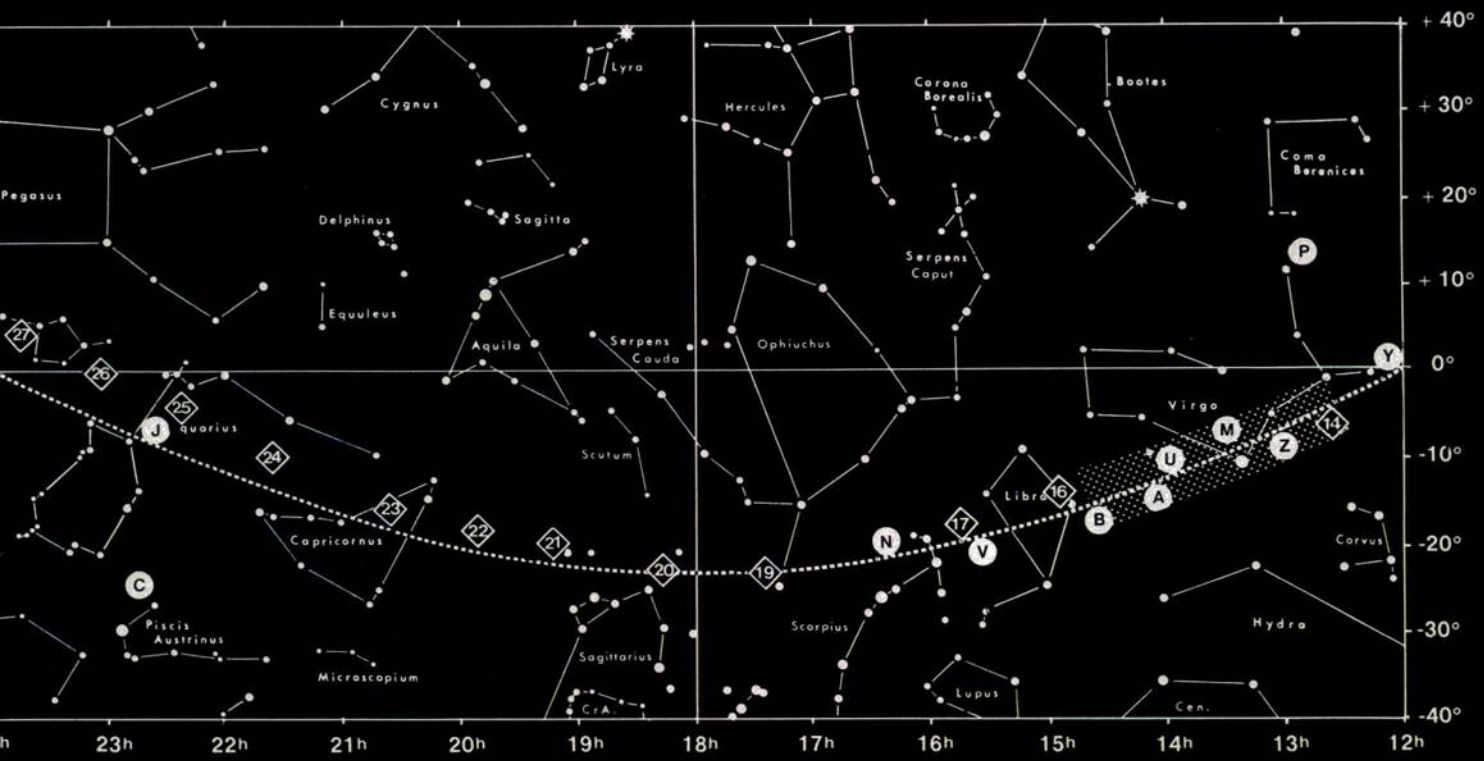
Ⓟ Pluto

Oct.	15
R.A.	12h51m
Dec.	+12°07'
Mag.	+14.3

First Quarter
Oct. 22

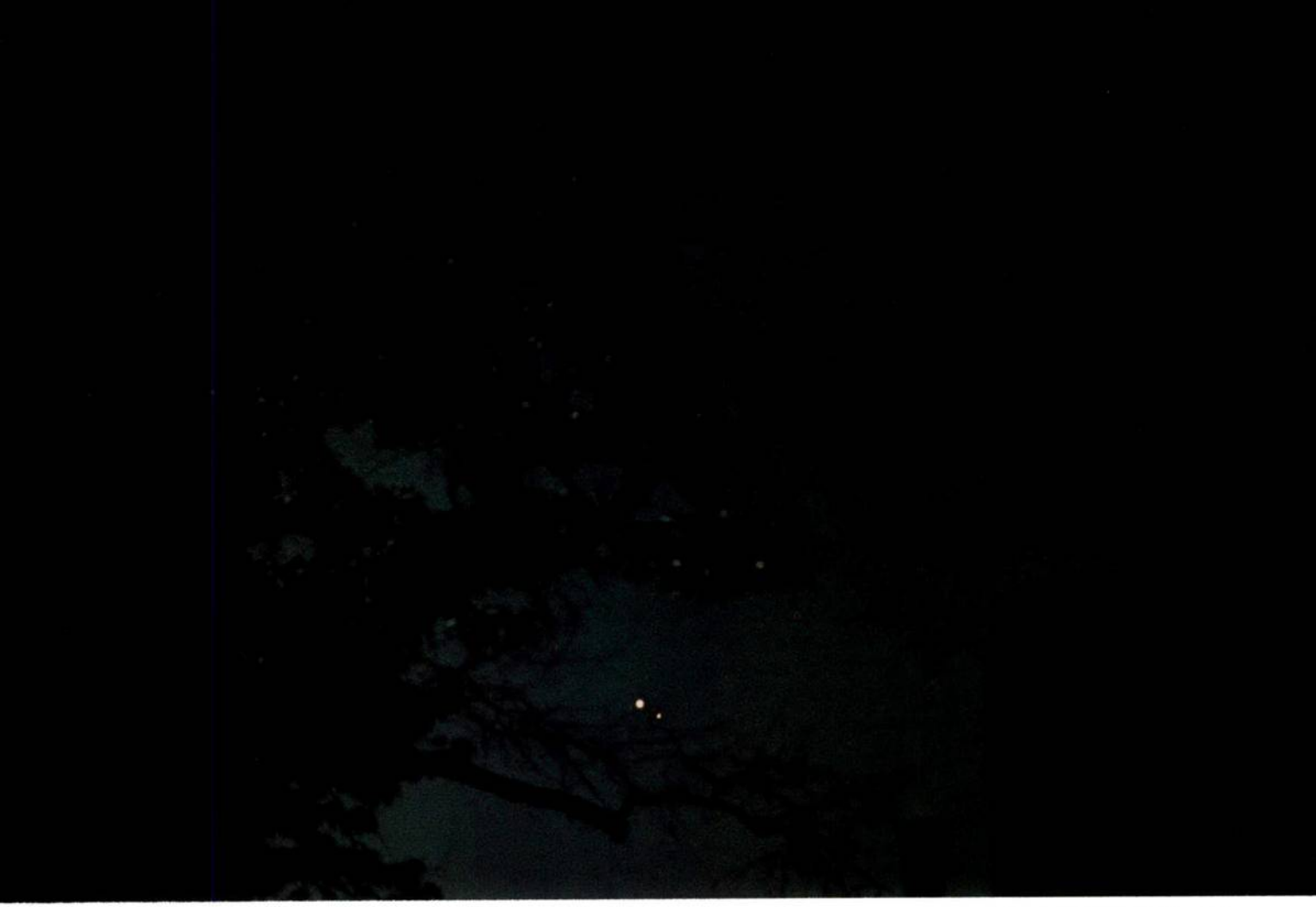
Full Moon
Oct. 1 and 30

Last Quarter
Oct. 8



measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) **Dia.** = the planet's apparent diameter in seconds of arc. The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th.

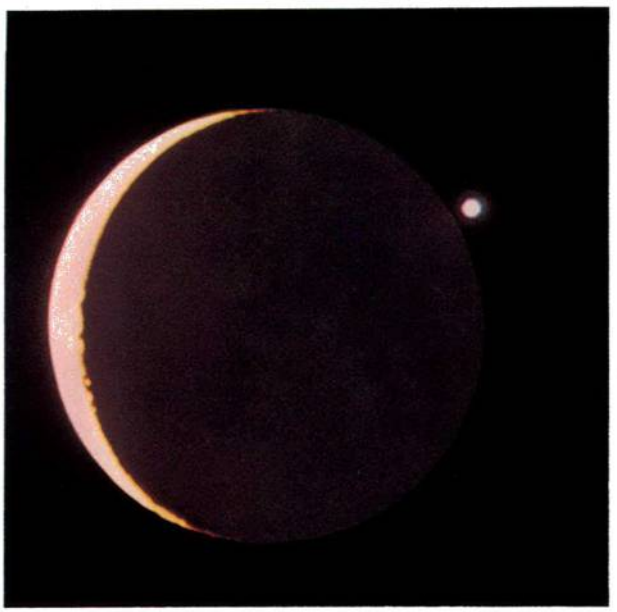
Artwork by Victor Costanzo



Photograph by Fred Espenak

Photograph by Terry D. Oswalt

The moon gradually moved away from Venus after the occultation. Some unlucky observers were clouded out and missed the earlier parts of the event, including those at this site near Milwaukee, Wisc.



Photograph by James C. Baize

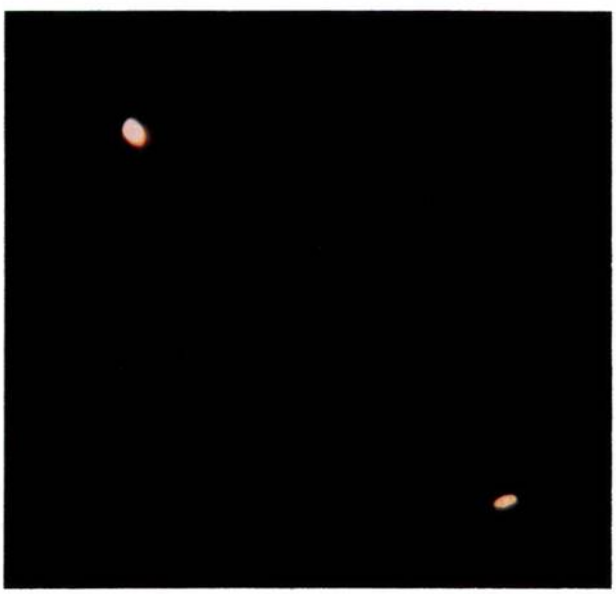
As Venus peeked from behind the moon on July 17, 1974, its brilliance was a distinct contrast to our satellite's night side (seen here faintly illuminated by reflected sunlight from Earth).

pondence ranged from reports of surprise and delight from those observing their first meteor shower, to detailed accounts by seasoned amateurs.

Most observers logged between 20 and 30 meteors per hour between 10:30 p.m. and 1:30 a.m. on both nights of the shower — close to ASTRONOMY's predictions (Gazer's Gazette, August 1974). Almost everyone reported seeing at least one brilliant Perseid of magnitude -3 or brighter. Here is an account of an exceptionally bright meteor (often called a fireball) seen by Joseph Rao who was observing with several other members of the Amateur Observer's Society of New York City:

"I looked down at my tape recorder planning to insert a fresh cartridge, when it suddenly became illuminated by something which I thought at first was the dull light of one of my colleagues' heavily filtered flashlights. I instinctively looked up and was stunned by a great fireball in its final stage, moving almost due south, quite slowly into northern Sagittarius. The light emitted by this meteor was intensely green and seemed to have a very slight vapor trail — but it looked overall like a ball from a Roman candle. It was definitely a Perseid."

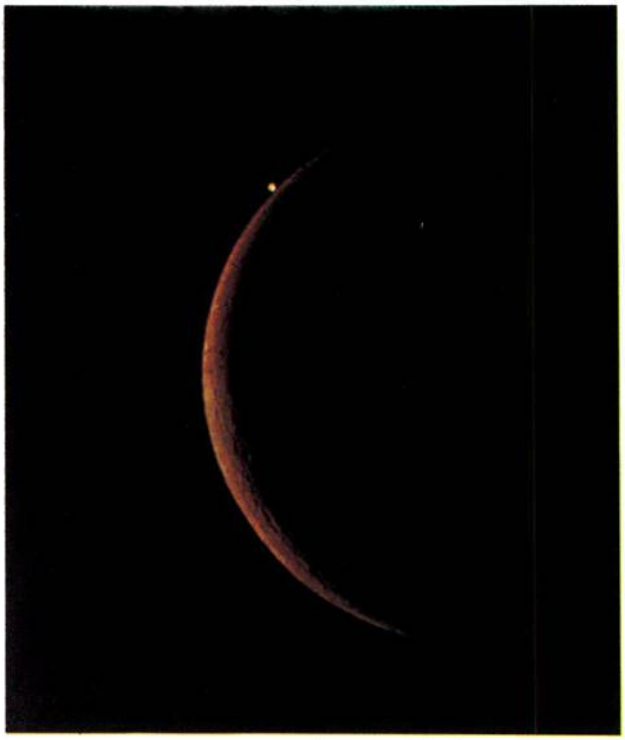
This spectacular object was estimated to be at least magnitude -10 (about the brightness of the first or last quarter moon). Those of us who have never seen a Perseid meteor that bright are envious — but wait until next year!



Photograph by Larry Koehn

Venus and Saturn formed a striking double star in the early dawn of July 31, 1974. Although nowhere near each other, the alignment of the three planets — Earth, Venus and Saturn — was very nearly a straight line; therefore Venus and Saturn appeared together from Earth. Top photo at left is a four second exposure on High Speed Ektachrome with a 135mm lens at f/2.8. Lower left a 50mm lens at f/5.6 was left open for eight seconds on Kodachrome 64. At right is a medium power view of the two planets through a 10 inch f/8 Newtonian reflector. Venus was a nearly circular dazzling white ball making Saturn and its rings look dull by comparison.

Photograph by Richard Sanderson



Photograph by Leo C. Henzl Jr.

At nearly the same instant the cover photo was taken, this picture was snapped at a location 700 miles farther west near Chicago, Ill. The 1/8 second exposure was taken on High Speed Ektachrome (pushed to ASA 400) through an eight inch Schmidt-Cassegrain telescope.

Orionid Meteors

A junior version of the Perseids is due the early morning of Monday, Oct. 21. The shower is called the Orionids because the meteors seem to originate from a region just north of Orion's second brightest star, Betelgeuse. (The pronunciation "beetle juice" is now reluctantly accepted in most astronomy circles.)

This is definitely an "after midnight" display. Expect few Orionid meteors before midnight — especially this year, with the first quarter moon glaring in the west. Moonset is around 11:00 p.m. local daylight time and that's a good time to begin preparing for the vigil.

At its best, probably around 3:00 a.m., the Orionids produce 15 or 20 meteors per hour. Add the 5 to 10 sporadic meteors that always are plunging into our atmosphere and you get a maximum of 30 meteors per hour for a dark sky location.

In previous years, typical Orionid meteors left trails that lasted longer than other meteors of equivalent brightness. This is undoubtedly connected in some way to the makeup of Halley's comet since these meteors are in fact "leftovers" from this famous object. All comets eventually disintegrate into meteor swarms and Halley's is partly into that process at this time.

1974 TEN YEARS SPRINGER-VERLAG NEW YORK

A Journey Through the Invisible Universe and the World of Radio Astronomy

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By **G. L. Verschuur,** University of Colorado, Boulder, Colorado

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1974. 192p. 70 illus. paper/$5.90
Heidelberg Science Library Volume 20

Galactic and Extra-Galactic Radio Astronomy

Edited by **G. L. Verschuur** and **K. I. Kellermann**
National Radio Astronomy Observatory, Green Bank, West Virginia

This book is concerned with the observational aspects of modern radio astronomy outside the Solar System. It begins where most textbooks on radio astronomy leave off, with a discussion of what is actually known from research in the field. Emphasis is placed on the type of data available and its interpretation. The book is aimed at graduate students and practicing astronomers, but is also suitable for senior astronomy courses.

1974. 440p. 127 illus. cloth/$37.80

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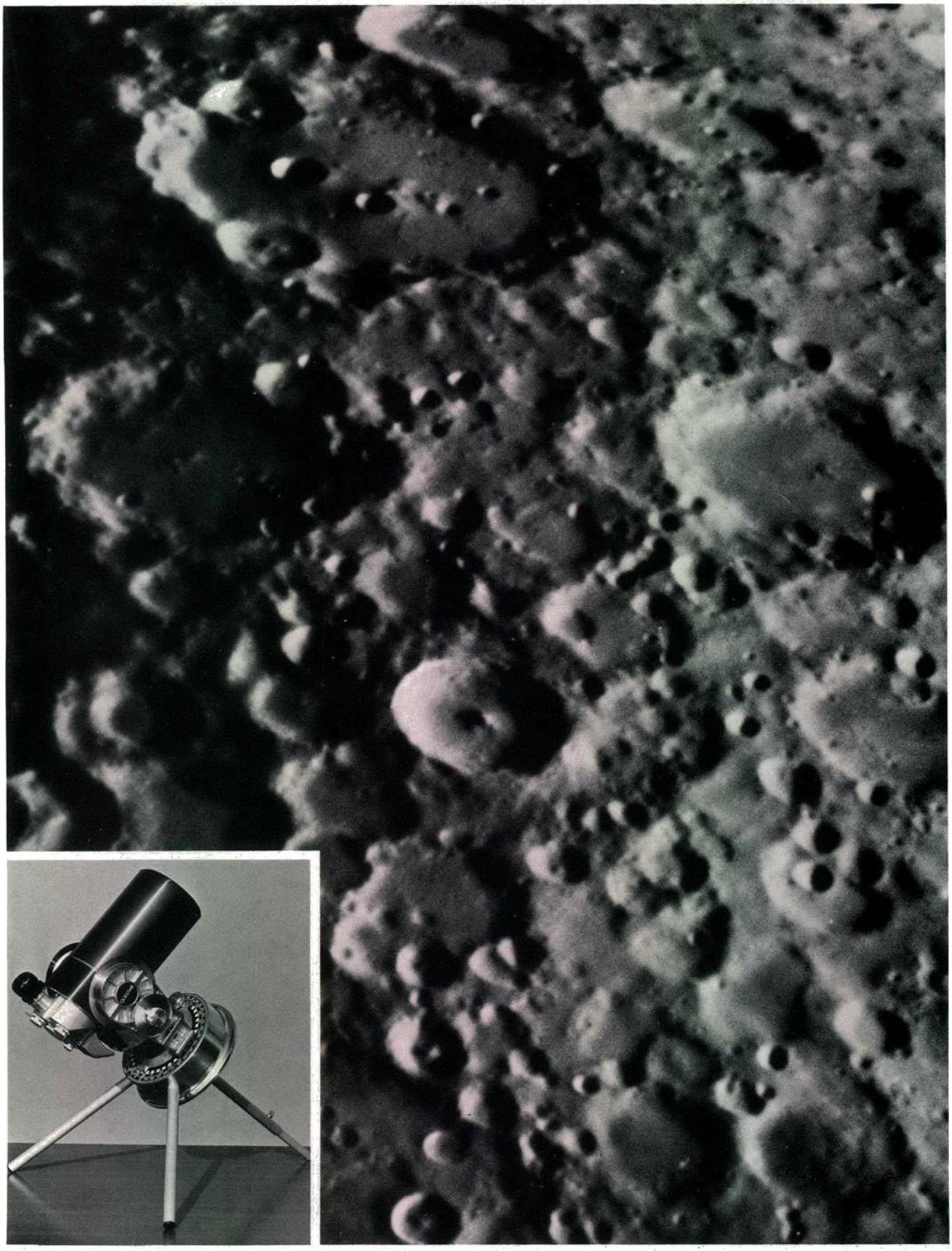

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The New Space Encyclopedia

by SIR BERNARD LOVELL, et al

326 pages, hardcover, $14.95
E. P. Dutton & Co. (1973)

This handsome volume is subtitled, "A guide to astronomy and space exploration". It serves just as well as a guide into astronomy and space exploration for the interested beginner. It is a tempting, beckoning, seductive book — calling experts and novices alike into one of this century's most exciting fields.

The excitement and mystery of astronomy in the 1970s is beautifully communicated through hundreds of entries, tables, and appropriately selected illustrations (many in magnificent color). This is a book for the person who wishes to know more about these subjects but doesn't think he has the time or patience to read the entire text at once. You can dabble in various subjects as your curiosity is aroused; eventually you will have read the book cover to cover.

As an up-to-date encyclopedia of a rapidly changing field, the book discusses pulsars, quasars, black holes, Apollo and Skylab, but stops short of the most recent discoveries about Jupiter and Mercury. Nevertheless, all the background you need to understand and appreciate the space and astronomy advances for the rest of the 1970s will be found here.

Such a tremendous project, involving the efforts of about 20 contributors, is bound to have problems with minor errors, omissions, quality control and coordination. There were 10 — not 9 — manned Gemini flights, and only 7 — not 30 — Surveyor moon probes. There is regretably no entry for "magnetosphere" or "magnetic fields" nor for "polarized light" and its implications in measuring galactic magnetic fields. The Russian space program gets poor quality and quantity of coverage. The Space Shuttle, America's permanent bridgehead into space for the next few decades, deserves more than the five lines it gets. And five moons of Saturn have separate entries under their own names, while five others do not (apparently arbitrarily).

These criticisms are, of course, minor. The need for this generally excellent encyclopedia is very great in today's world, where experts and amateurs alike try to digest and evaluate discovery after discovery in space.

Whitney's Starfinder

by CHARLES A. WHITNEY

126 pages, paperback, $4.95
Alfred A. Knopf (1974)

Here it is — another guide to the sky. "Like a guide to a strange city, it helps you know your way around the heavens — with beautifully reproduced charts and all the information you need...." So says the blurb on the back cover of this new entry into the guide-to-the-heavens literature.

Does **Whitney's Starfinder** stand up to its billing? Will it, like Mayall's **Sky Observer's Guide** (Golden Press) and Menzel's **A Field Guide to the Stars and Planets** (Houghton Mifflin), become the beginner's "bible" that is recommended by high school science teachers and planetarium lecturers? The answer is a very definite *yes*.

Whitney packs each sentence of this little book with some important fact or guideline. But it's not stilted or heavy reading — just the opposite. His style is light and in many cases superior to any other book in its class. Whitney takes the novice into the night sky by selecting the brightest objects first and suggesting how they cannot be confused with satellites or aircraft; he then proceeds to identify them as planets and stars.

The book is full of tips: How planets and stars look different in the sky; what the planets look like through binoculars; determining time by the sun and stars; brief hints on observing sunspots; northern lights; halos and sun dogs and more.

There is a very complete set of useful tables throughout the book: the Greek alphabet; the 30 brightest stars; a table of solar and lunar eclipses; significant events in the sky from 1974 through 1977; a planet almanac; the phases of the moon and others.

Tucked away inside the back cover is a circular starfinder, very cleanly designed and complete. (You can dial the hour and date to select the sky that is above you at any particular time.) However, it's a little presumptuous of the publishers to call this starfinder "ingenious" — it may indeed be ingenious, but starfinders of this type have been around for several decades.

One of the few things Whitney didn't do was to identify the main guideposts of the sky more clearly. The natural pointer stars in the Big Dipper and Orion were overlooked. This is the book's only major shortcoming, and if you follow the Star Dome department in this magazine fairly regularly, that particular aspect of star identification is thoroughly covered.

One unfortunate blunder is the map of the Pleiades which was reversed somewhere in the production stages and comes out looking a mirror image of the way the stars appear in the sky. For someone unfamiliar with the Pleiades cluster, this chart will cause considerable confusion.

Despite this error and the omission mentioned above, **Whitney's Starfinder** should be a must for any beginning astronomy enthusiast. This book is also a perfect primer for the Gazer's Gazette and Sky Almanac departments of this magazine.

Books are expensive — especially astronomy books. Seldom is one priced under $5.00, and some cost as much as a two year subscription to this magazine. So great care should be taken to make sure you get the right book for your level of experience and sphere of interest.

That's the purpose of this department — to outline in plain language what a book is about and whether it suits your particular desires for more information. We won't hesitate to point out a book's good and bad features. We're not trying to sell books — we're trying to let you know what's available. This, then, is a sort of consumers' guide to astronomy books.

We've had the SUPERSTARS! Poul Anderson / Piers Anthony / Richard Ashby / Dr. Gregory Benford / Ray Bradbury / John Brunner / Ed Bryant / F.M. Busby / Terry Carr / Philip K. Dick / Scott Edelstein / Larry Eisenberg / Harlan Ellison / Roberto Fuentes / Stephen Goldin / James Gunn / Harry Harrison / Robert Heinlein / Frank Herbert / Walt Liebscher / George R. R. Martin / Larry Niven / Rachel Cosgrove Payes / Dr. Jerry Pournelle / William Rotsler / Joanna Russ / Neil Shapiro / Robert Silverberg / Norman Spinrad / James Sutherland / A. E. Van Vogt / and Ted White / **So guess who's coming next in VERTEX!**

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OCTOBER

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet

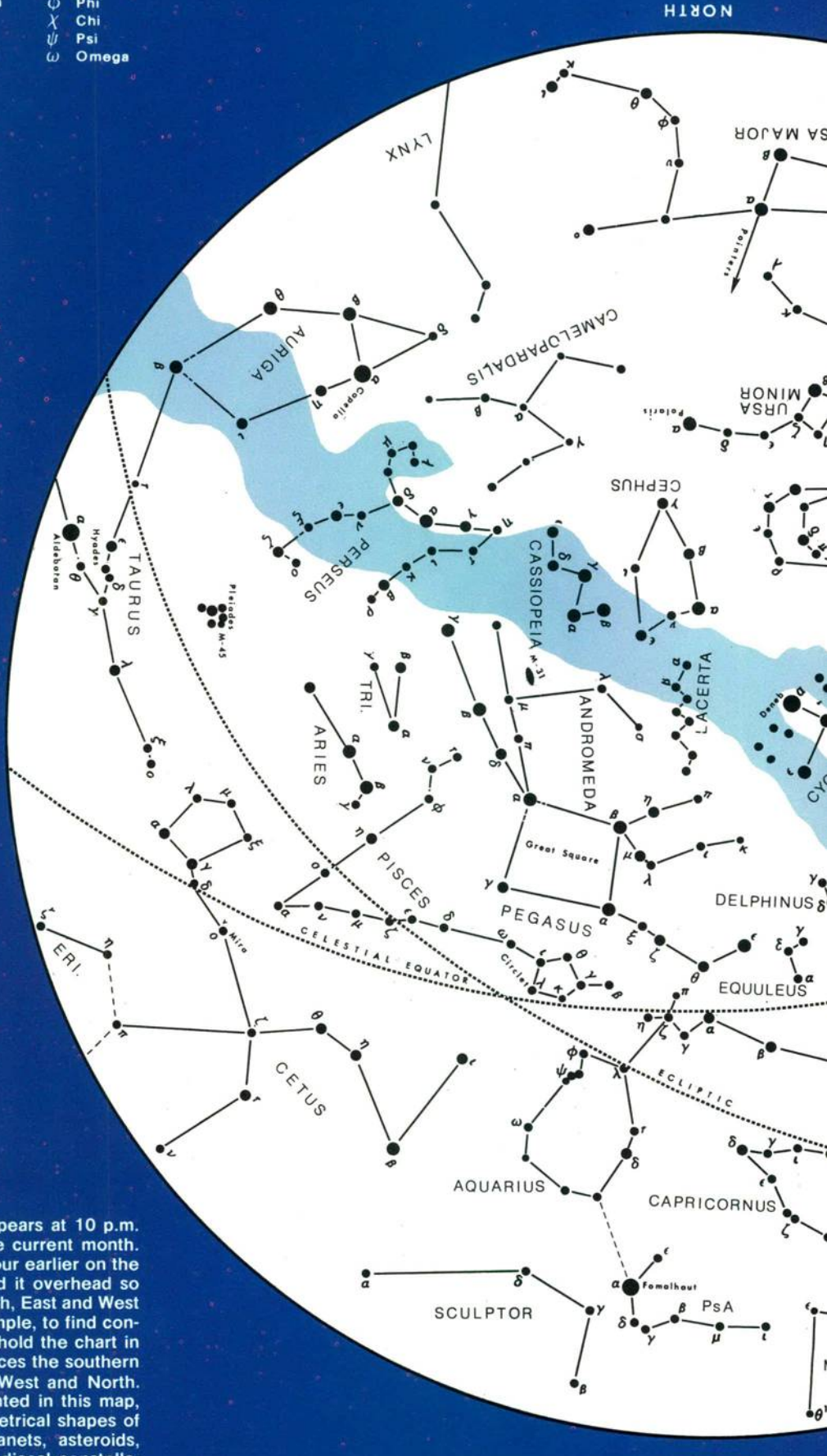
α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ε	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

MAGNITUDES

- Zero
- First
- Second
- Third
- Fourth
- Fifth

OBJECTS

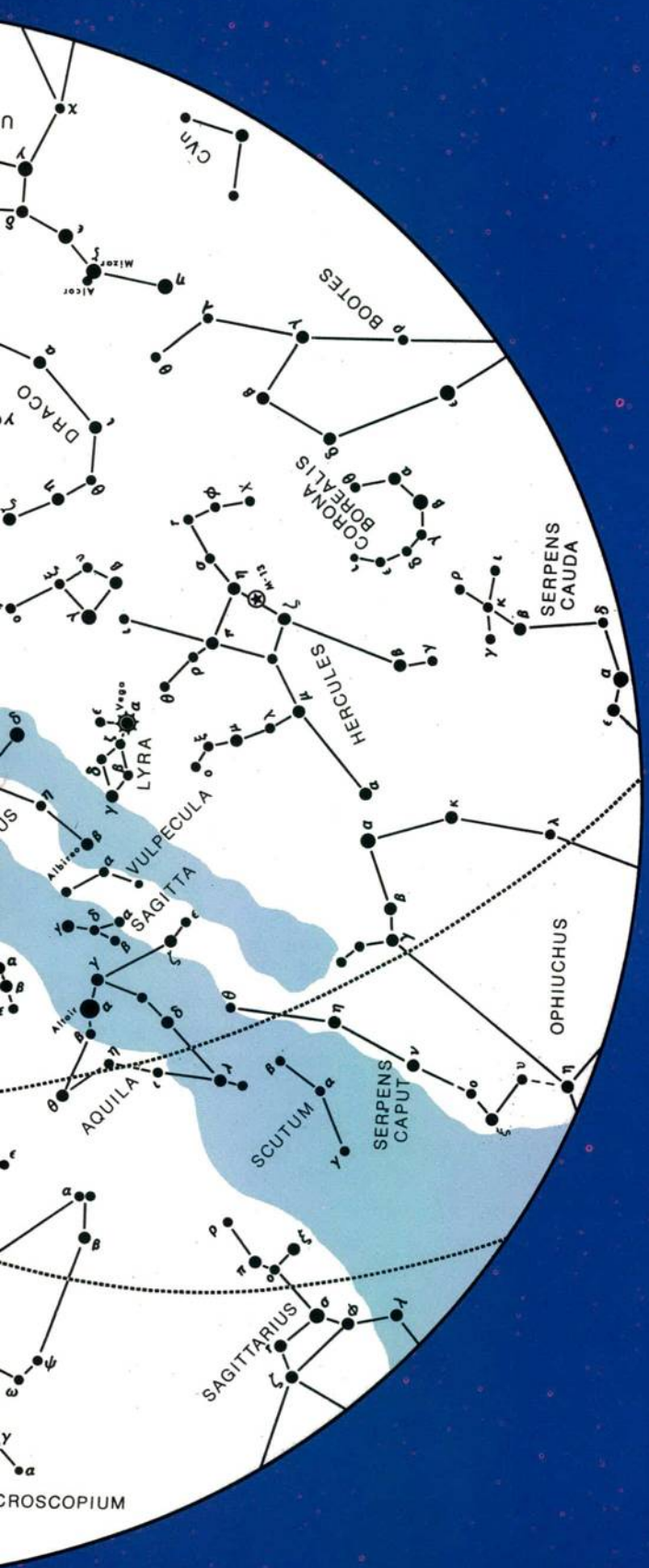
- Open Clusters
- Globular Clusters
- Diffuse Nebulae
- Galaxies
- Double Stars
- Variable Stars



Star Dome approximates the sky as it appears at 10 p.m. Local Daylight Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder in Sky Almanac.

Map Centered on 43° North Latitude

STAR DOME



Map by Raymond G. Coutchie

"What's that bright object over there in the southeast?"

If you asked this question and then found the answer in Sky Almanac (the object is Jupiter) you may wonder why we don't put Jupiter on the chart that appears on this page.

Well, we don't do it for several reasons. The main one is that we have a separate chart that shows where the moon and planets are during the month. (That chart appears in this issue on pages 36 and 37.) If we tried to show everything that is on that chart on the circular chart here, it would then become somewhat cluttered. In addition, it's impossible to show everything from the Sky Almanac chart on this circular chart because they are two different types of sky maps.

This circular chart shows the sky as it appears at the evening hours indicated from practically anywhere in the United States and southern Canada. What it does not show is the other half of the sky — the half below the horizon. You can see some of the missing half if you stay up late and let the rotation of Earth carry the stars from east to west in its endless celestial procession. Just before dawn most of the stars here will be gone, and the stars that we will see in the evening in wintertime will have risen high overhead. Throughout the year you can get this preview of the following season's evening constellations by simply staying up after midnight.

But to get back to the point, this chart shows only half of the sky. The long rectangular chart on pages 36 and 37 shows the entire equatorial region of the sky.

Let's suppose that you stand back from Earth somewhat so that you can view the entire planet. We'll draw an equator around Earth so that you can see it. Now let's further suppose that this equator is elastic and is infinitely expandable. The equator is now expanding — it's moving out like radiating ripples on a placid pool after you toss in a stone. The elastic equator is moving out into space getting larger and larger, but ever remaining over the real equator of Earth. Soon it gets so far out into space that it's out among the stars, but we'll presume that you can still see it — it's magically illuminated out there. Our equator is now fixed. It remains in the same position relative to the stars as the stars are to each other.

We have just "constructed" one of the main coordinates in the sky — the celestial equator. You can find it running across the middle of the rectangular chart and also cutting across our circular map (both are marked equator). The

Photograph by Patrick Michaud

This island of stars similar to the Milky Way galaxy is over two million light-years distant; yet it is so huge that it is clearly visible to the unaided eye. Marked M-31 on the map on the preceding page, it is better known as the Andromeda galaxy. In a small telescope its wispy outer arms can be glimpsed — as well as NGC-205, the small companion galaxy right and slightly above the nucleus of M-31. The bright star at lower left is Mu Andromedae which appears slightly brighter than M-31 to the unaided eye. See Constellation Close-Up for more details.

celestial equator, then, is nothing more than an extension of Earth's equator out into space. If you stand on Earth's equator in Quito, Equador for example, the celestial equator would appear exactly overhead (assuming you could actually see it). As the stars pass in review during the night, the equator would stay straight overhead. For us in the U.S., the celestial equator is below the zenith (overhead point) by exactly the same amount that we are north of the equator. Thus if your latitude is 40 degrees, the celestial equator will appear south of the zenith by 40 degrees. (Apparent relative distances are measured in the sky in degrees — 90 degrees being the distance from the horizon to the zenith.) So the celestial equator would be 40 degrees south of the zenith and 50 degrees above the southern horizon — both of them adding up to the 90 degree distance between the horizon and the zenith.

What about that curious wavy line marked ecliptic that loops above the equator on the left side of the rectangular chart and below the equator on the right side? The part of it that is in October's evening sky is shown on our circular map. The reason that it's wavy has to do with the tilt of Earth's axis relative to its orbit. But that's not important; the important thing is that the sun, moon and planets always appear near this line. Since the sun, moon and planets can be anywhere along this line, we have to show the whole thing — not just the half that happens to be in the sky this evening. So that's why we have two charts: one to show the positions of the sun, moon and planets in the entire sky, and the other one to show the stars that you can see this evening in more detail.

How do the two maps relate? Take a constellation on the Star Dome map that is on or near the ecliptic, such as Aquarius. Now find Aquarius on the rectangular map in Sky Almanac. You can see that several of the constellations on the circular map are also shown on this rectangular map. The area common to both maps is the area that is overhead. The rest of the rectangular map is either visible in the morning sky or if it's near the stippled area, is washed out by the sun. There is always about 1/4 of the sky that the sun happens to be in and therefore is rendered invisible simply due to the sun's brilliance.

If you find this type of description helpful, let us know and we'll do it more often.

ASTRO-NEWS

Latest News From the World of Astronomy

Two Probes to Examine Weather on Venus

When two Pioneer spacecraft arrive at Venus in 1978 to probe that planet's murky atmosphere, the information they gather may also help us learn more about the planet Earth. The study of weather patterns on other planets — and on Venus in particular — can provide clues to the mysteries of our own weather system.

On Earth, the basic causes of weather patterns are not clearly understood — as evidenced by the shifting tornado and hurricane paths that catch communities unaware every year. Many factors complicate Earth's meteorology. Mixing of oceanic and continental air masses, cloud formation, axial tilt and rapid planet rotation make our atmosphere difficult to study.

But Venus is simpler to study because it has a basic atmosphere that is 95 percent carbon dioxide, a very slow rotation (117 Earth days equals 1 rotation of Venus), very little tilt to its axis, and no oceans. If scientists can understand how these variables affect the atmosphere of our closest planetary neighbor, they hope to be able to define more clearly the impact of the numerous variables in Earth's weather system.

Venus is about the same size as Earth but has an atmosphere 100 times as dense as ours. If Earth were as close to the sun as Venus, it would probably be a similar world. At Venus' distance (about 2/3 Earth's 93 million miles), the sun's heat is great enough to evaporate oceans, releasing much of the carbon and oxygen trapped in the water and land of our planet.

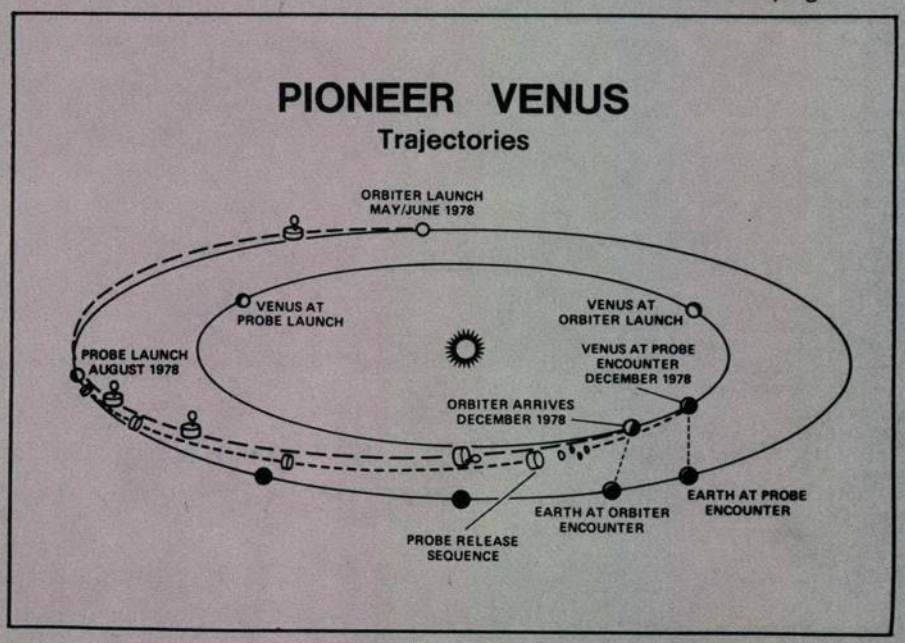
The two-spacecraft mission to Venus consists of an orbiter and a multiprobe spacecraft, to be launched in May and Aug., 1978. Both spacecraft will arrive at Venus in December of the same year, with the orbiter slated to arrive five days before the probe-carrying spacecraft. To accomplish this timing, the orbiter will be launched on a trajectory which will take it more than 180 degrees around the solar system in eight months. The atmospheric probe's trajectory will be a direct path from Earth to Venus, requiring only four months.

The orbiter, carrying 185 pounds of instruments, will be placed in an elliptical orbit which will bring the spacecraft to within 125 miles of the surface — with a maximum distance from the planet set at 37,300 miles. Most of the data gathering will occur when the craft is closest to the planet, about one hour per day. The orbiter is designed to study the Venusian atmosphere over an eight month period.

The second spacecraft will carry four separate probes which will be released about 20 days before penetration of the atmosphere. The probes will be targeted to different locations on the planet's surface. The probes' descent through the atmosphere to the surface will take about 70 minutes. No attempt will be made to keep the probes "alive" after impact. The main spacecraft will burn up after plunging to within 80 miles of the planet's surface, but it will make some brief upper atmosphere tests on the way down.

Three of the four descent probes are small — weighing about 160 pounds each, including six pounds of scientific instruments. The probes' heat shields and pressure insulation comprise most of the bulk weight. The probes will record how fast they fall toward the surface and constantly

VENUS *continued on page 49.*



Does the Moon Influence Your Moods?

For centuries man has pondered the moon's effect on his fate. Even the quality of wine or buttermilk, and the right time for possum and coon hunting have been linked to our "lamp of the night".

Today the romantic, mystifying moon, so often woven into ancient folklore, has been given a more authentic aura. Yet continuing research seems to confirm — rather than refute — our satellite's influence on living matter.

Neuropsychiatrist Leonard J. Ravitz of Duke University's School of Medicine has argued that man is an electrical system like all living beings. "It is difficult to imagine him not being affected in measurable ways" by the changing phases and positions of the moon, which influence the electrical properties of the atmosphere.

Just as the moon raises tides in the ocean, so it produces "tides" in the atmosphere. Three or four days after the moon is new or full, the band of frequencies that can be used to get radio broadcasts through to distant stations is slightly narrower in some parts of the world than in others. An official of the National Bureau of Standards at Washington, D.C. suggested to ASTRONOMY that these variations are due to electromagnetic fields which are set up in the atmosphere by lunar variations.

Ravitz's findings add weight to earlier experiments by Harold S. Burr of the Yale School of Medicine which suggested that living things have electrical rhythms approximating the near-monthly lunar cycle.

Burr inserted a set of electrical contacts into the trunks of living trees about five feet apart and at a depth next to the cambium, the growing layer of trees. A delicate recording apparatus revealed that once a month there was a very sharp rise in the electrical voltage or pressure. Records of temperature, humidity, and barometer were maintained. None of these were found in step with the changes in the trees' electrical state. Yet a change in voltage was conclusively recorded at the time of a new or full moon!

The gravitational attraction of the moon actually distorts solid ground, raising a bulge several inches high. This bulge is not stationary but travels around the globe so as to be always under the moon. This Earth tide actually changes the longitudes of Washington and Greenwich enough so that at times they are closer together by several feet. In addition, Professor Harlan T. Stetson of the Cosmic Terrestrial Research Laboratories of the Massachusetts Institute of Technology has demonstrated that some earthquakes may be triggered by the moon's pull on Earth's crust.

In folklore there are hundreds of theories and fantastic superstitions about the moon's effect on crops, but there actually is a flower — a South African member of the iris family known as *Morea iridoides* — that blooms only in accordance with lunar phases. University of California scientist Knight Dunlap noticed that the Moreas bloom normally within two periods in each lunar month. "One period commences on the date of the first quarter and ends the day before the full moon. The other period runs from the date of the last quarter up to the new moon. During full and new moon there are no blossoms," he said.

The seaworm *Eunice viridis*, found in the South Pacific, spawns only during full moon. As the rays penetrate the water, the worms emerge from their burrows and lay their eggs, responding as if their bodies were photoelectric cells and the moon some eerie goddess calling them forth and giving life. "And so, if these external forces can influence Earth's physical, vegetable and animal forms, they might also influence the electrical fields in man," said Ravitz.

Yet Ravitz is the first to point out that the nature of the moon's electrical influence is still unproven. "In fact," he cautiously stated, "evidence suggests that the amount of moonlight (only 1/300,000 as intense as sunlight) is definitely not a factor in these studies." However, he admitted that "inherent protoplasmic rhythms may have lunar periodicity". In other words — protoplasm, the very substance of life, has electrical rhythms which may show changes that keep step with the phases of the moon.

In his experiments at Yale and later at Duke University, Ravitz used a microvoltmeter which measures the delicate electrical properties of living systems. His original studies, however, were concerned only with the changes in direct current as related to changes in human emotions. Unexpectedly he came upon the moon cycle and its apparent harmony with the electrical rhythm of man.

Seventeen subjects (11 men and 6 women) were measured electrically every day for from one to eight months. Careful notation was made of mood fluctuations and emotional disturbances. The first results were vague. Minor mood swings could not be correlated with direct current alterations. However, despite complex individual variations, there appeared in the subjects considerable increases in electrical potential which astonishingly occurred approximately at the time of the full and new moons!

During the full moon the Duke University scientist found that moderately maladjusted students showed increases in sullenness, general irritability, hypersensitivity, preoccupation, and to some extent withdrawal from people and all social activities. They felt best shortly following the new moon. The severely maladjusted showed a similar cyclic rhythm with a higher voltage reading than the others and with sharper up and down swings.

"Eventually we may be able to predict our own mood cycles from such microvoltmeter readings, for we did find in our experiments periods in which the students were going to feel best and others in which they will be less emotionally stable," Ravitz said.

A definite basis for the moon's effect upon the mentally unbalanced has been found in the psychiatric wards of the Roanoke Veterans' Hospital in Virginia. Once again the severely maladjusted were the most sensitive to lunar phases.

Thus, it was not only superstition when Paracelsus, as early as the 16th century, claimed that the insane grew worse at the dark of the moon when its attraction upon the brain was believed to be the strongest (hence, the term lunatic).

Further research into this specific area was recently conducted by Arnold Leiber of the University of Miami. He investigated the murder rate in Miami over the past 15 years and found definite peaks at new and full moon. To make sure his conclusions were not due to random factors, he examined the Cleveland, Ohio homicide files and found the same relationship. Leiber noted that homicides occurring when new or full moon coincided with lunar perigee (moon nearest Earth) "were often of a particularly bizarre or ruthless nature".

An Atmosphere on Pluto?

The most distant planet is certainly the least known. Pluto orbits the sun at an average distance of 3.6 billion miles and has a diameter less than 1/2 that of Earth. At that tremendous distance it is impossible to see it as anything but the tiniest point of light.

However, in examining that tiny point of light several things have been determined. Pluto's rotational period is known (6 days 9.3 hours) and spectral examination of Pluto reveals no known atmosphere. Now an ingenious suggestion for an undetectable atmosphere on Pluto has been proposed by Michael H. Hart of the Hale Observatories of the California Institute of Technology and the Carnegie Institute of Washington.

Hart has pointed out that at the 390 degree temperature on Pluto, the only gas that can exist over a long period of time without escaping from the planet's surface is neon. Neon would not be detectable spectroscopically from Earth and would only reveal itself when the distant planet's brightness is measured in ultraviolet wavelengths. Such observations have been made and do not show evidence of a neon atmosphere.

But the atmosphere would have to be more than three times as dense as Earth's atmosphere in order to show up. So Hart has proposed a neon atmosphere which could be quite plausible for Pluto.

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Satellites Zap Radio Astronomers

Two satellites recently launched by NASA are causing interference in radio frequency bands allocated — by international agreement — for use by radio astronomers. A worldwide group known as the International Telecommunication Union meets periodically to decide who shall use what airways. Meteorology, astronomy, AM and FM radio, television, maritime, aviation and many other groups vie with one another for particular parts of the radio spectrum.

Radio astronomers are particularly concerned that those parts of the spectrum allocated to their use should remain free of outside interference produced by transmitters on Earth, in the air and in space. Such interference could easily wipe out all signals reaching us from outer space if steps aren't taken to protect parts of the spectrum.

Now, however, ATS-6, an educational satellite, is blasting one radio astronomical band at 11cm (2690-2700 MHz) while a meteorological satellite, SMS-1, is zapping part of the 18cm band which is where the main lines of the interstellar OH molecule radiate naturally.

The problem is that since radio astronomy receivers are extremely sensitive, signals from ATS-6 can easily be picked up at least 20 degrees away from the direction of the satellite. In the case of the SMS-1 satellite, which is but the first of a worldwide network of geostationary meteorological satellites, the interference generated in the OH band is so great that it is possible that observation in any direction of the sky would be wiped out by the transmitter on the satellite. Already radio astronomers in England have found that SMS-1, hovering over the United States, is easily picked up by them.

There is little that the radio astronomers can do to stop this incursion on their interference-free parts of the radio spectrum. While there are guidelines in the U.S. that determine the level to which one can pollute the airwaves, and while radio astronomers have specified harmful interference levels in each of their allocated bands, the radio astronomers are fighting hard to convince others that the 11cm and 18cm bands are being seriously threatened. What would otherwise be an acceptable level of interference for a ship-to-shore band, for example, would wipe out the signals from quasars. By analogy, optical astronomers would be very upset if searchlight beams crisscrossed the night sky.

VENUS *continued from page 47*

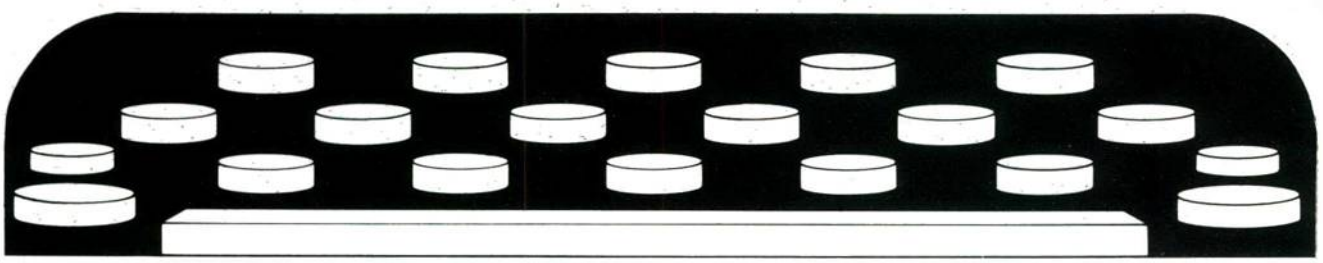
measure atmospheric pressure and temperature. A nephelometer presently being developed at NASA's Ames Research Center will measure cloud extent and altitude and a net flux radiometer will be on board to look at changes in cloud densities and the exchange of heat energy between the sun and the atmosphere. The three probes will be tracked during the descent to give valuable information on winds and circulation patterns.

The fourth probe is larger, carrying about 70 pounds of instrumentation as part of its 605 pound bulk. The big probe will carry a mass spectrometer and a gas chromatograph that can identify the components of the Venus atmosphere.

This dual spacecraft mission will mark the first United States attempt to descend into the Venus atmosphere. A lander capable of surviving the torrid surface temperatures is as yet only in the preliminary design stages.

Another series of studies is focusing on balloon-borne instrument packages that can hover for months in the upper atmosphere measuring cloud and atmospheric composition and circulation. The Soviets are also engaged in similar design research.

Much of our knowledge of the surface of Venus has come from Soviet space probes. Two Russian spacecraft, Venera 7 and 8, landed on Venus in 1970 and 1971. Each craft operated there for several minutes and measured temperatures of 880 degrees above zero. They recorded the surface temperatures on the planet's night side to be almost the same as that of the daytime side — the density of the atmosphere easily holding in much of the heat absorbed from the sun. According to recent Mariner 10 data the cloudtop temperatures are much lower, averaging -35 degrees. At the surface on the daytime side of Venus about two percent of the sunlight reaches the surface indicating the cloud deck is not as dense as some previous estimates.



IN FOCUS

Sir / Although I do not wish to be overly critical of what was essentially a good article, I have to express some dismay with Ben Bova's ("What Chariots of Which Gods?", August 1974) lightweight criticism of Erich von Daniken's "evidence". The so-called evidence is hardly "equivocal", as Bova stated, but is demonstrably wrong. So well known a popularizer as Bova and as important a magazine as ASTRONOMY certainly share an editorial responsibility to avoid misleading the reader to think that there might be something to the "Chariots" notion.

Whether we were visited by ancient astronauts is not the point. It is important that we demonstrate how evidence is to be obtained and evaluated. Erich von Daniken's books comprise a rich source of examples of improper handling of data, and to say otherwise does a disservice to archeologists and others who do the hard work to piece together a picture of our own past.

E. C. KRUPP, Ph.D.
Griffith Observatory
Los Angeles, Calif.

Mr. Bova's reply to Dr. Krupp / I agree with your estimation of von Daniken's archeology. In the article I was "leaning over backwards" to avoid arguing with his archeology. The whole purpose of the article was to show that the astronomical background for von Daniken's thesis is unlikely to the point of absurdity.

Sir / On the evenings of June 5 and 11, 1974, I observed Mercury during its spring elongation. About 40 minutes after sunset I could resolve its crescent shape fairly easily in my 2.4 inch refractor at 178 power. I was very surprised at Mercury's great elevation; it was farther from the horizon than I have ever seen it except for the Nov. 1973 transit. Your June Gazer's Gazette on "Observing Mercury" was very helpful in locating and observing the planet. One of the best things about your magazine is the observing tips from experienced observers that are passed on to the amateur.

ASTRONOMY seems to get better every month. The "Planetary Bonanza" feature (June 1974) was outstanding. And I must say that your new *Instant-News* service is one of the finest, most original ideas I've heard of in a long time!

DAVID BUCKLEY
South River, N.J.

Sir / A crazy thing recently happened to me — I received the mailing cover of ASTRONOMY which had been split lengthwise all the way, and apparently the magazine had fallen out. There was, however, a magazine in the cover. Twine had been looped around both ways and tied to make sure it wouldn't fall out again.

You can imagine my great surprise when I untied the cover, took out the magazine, and found it was the June issue of **Playboy**. A **Playboy** magazine mailed out in an ASTRONOMY cover! So please send me my missing copy of ASTRONOMY — I sure don't want to be without it.

I. C. GUNNING
Wilburton, Ok.

Mr. Gunning / The postal service employees knew you were interested in heavenly bodies!

Sir / Can we have a section where experts answer readers' questions?

JAMES R. TIMIAN
Fargo, N.D.

Mr. Timian / This is it. We can't answer all the questions we receive, but we will select some for this department each month.

Sir / I believe the estimated number of stars in the globular cluster M-13 is one million — not one billion as stated under its photograph on page 72 in the July issue.

It would be more accurate to say that M-13 is over 30,000 light-years distant rather than "over 20,000 light-years distant" as the caption under the photo says. Most figures I have seen place the cluster at 33,000 or 34,000 light-years from Earth.

ROLAND RAINGE
New Salisbury, Ind.

Mr. Rainge / M-13 does indeed have an estimated one million stars. The most recent investigations of this huge globular cluster indicate it is just over 20,000 light-years away. The larger figures are from earlier studies.

Letters intended for this column should be addressed to The Editors of ASTRONOMY. Sorry, but the volume of mail does not permit individual replies.

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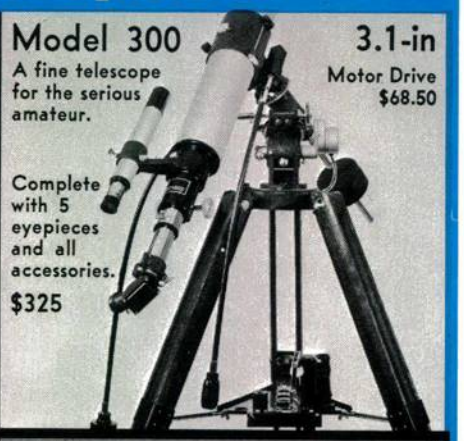

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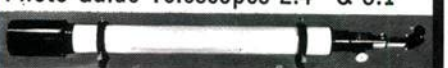

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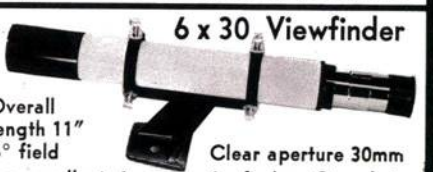

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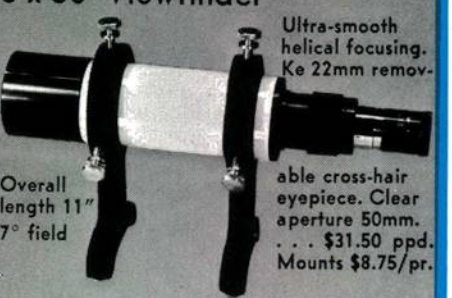

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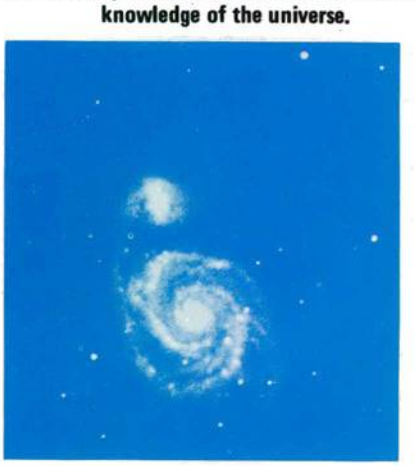

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CASTOR
EROS IN GEMINI JANUARY 1975
Jan. 18
Jan. 19
Jan. 20
POLLUX
Jan. 21
Jan. 22

Rendezvous With Eros

by
J. Lawrence Dunlap

This winter, a potato shaped asteroid known as Eros will be our nearest celestial neighbor beyond the moon. The 15 mile wide renegade from the asteroid belt will be only 14 million miles away in late Jan. 1975. At that time, the Manhattan sized chunk of space debris will be visible in small telescopes — appearing as an eighth magnitude "star" in the constellation Gemini.

Eros can get much closer to us than the nearest planets (Mars and Venus), but the closest approaches occur only at 44 year intervals; this is one of those rare occasions. When it is hurtling past us, the asteroid's motion will be noticeable after only a few minutes observation since it will be traversing the sky at over one degree per day. (Actually this swift rendezvous is a combination of the motions of both Eros and Earth.)

Although there are about two dozen other small asteroids which can come closer to Earth, Eros is about twice the size of Ivar (the next largest) and nearly 16 times larger than Icarus which was only four million miles away in 1968. The table on this page shows that the size of Eros more than compensates for the greater distance

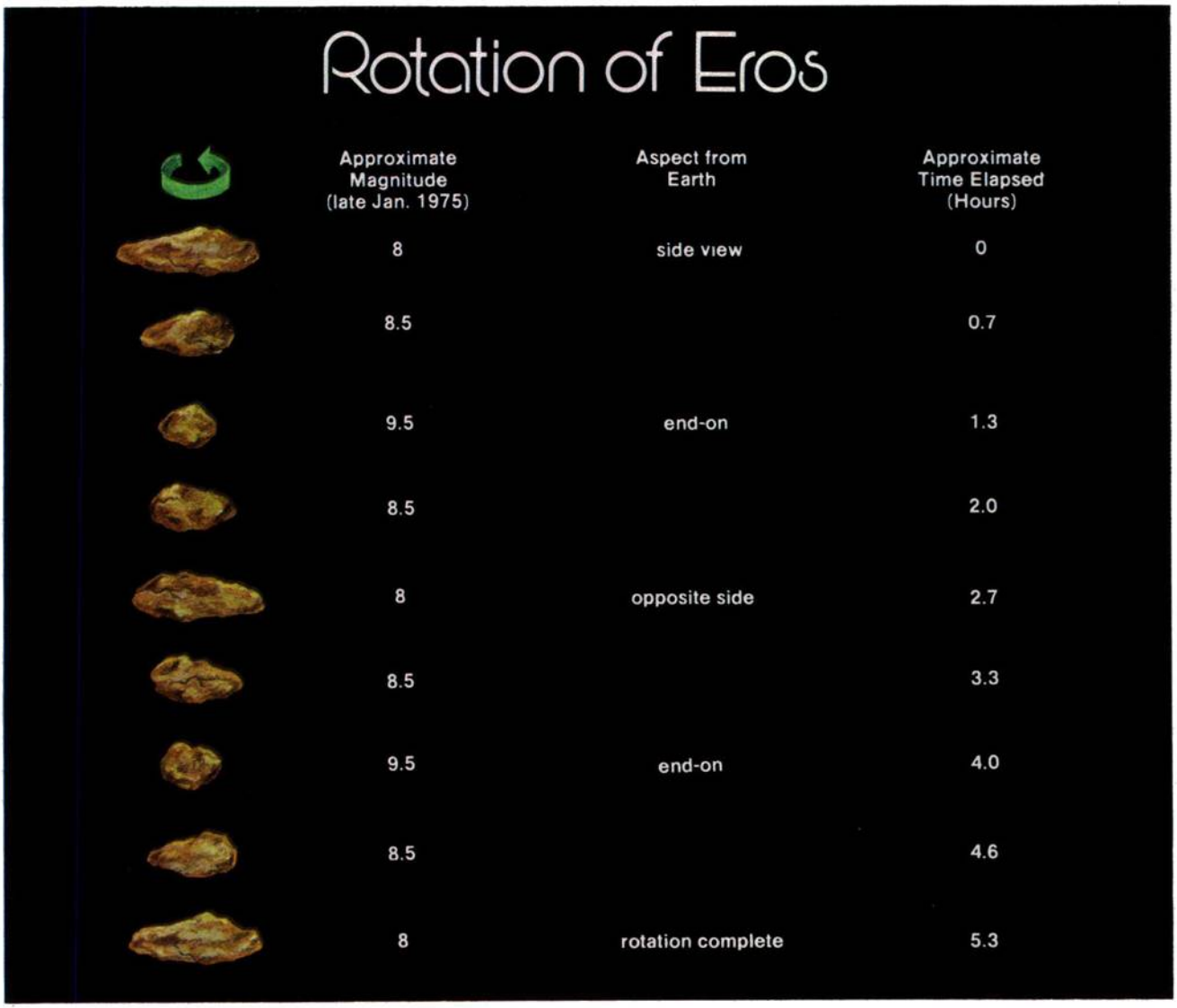
Recent Close Approaches of Asteroids

Asteroid	Date	Distance from Earth (millions of miles)	Diameter (miles)	Visual Magnitude
1566 Icarus	June 1968	4.0	0.8	12.2
1620 Geographos	Aug. 1969	5.6	1.6	11.1
1685 Toro	Aug. 1972	12	1.7	12.0
433 Eros	Jan. 1975	14	10-15(?)	8.0

The asteroid numbers are their catalog designations, applied in order of discovery.

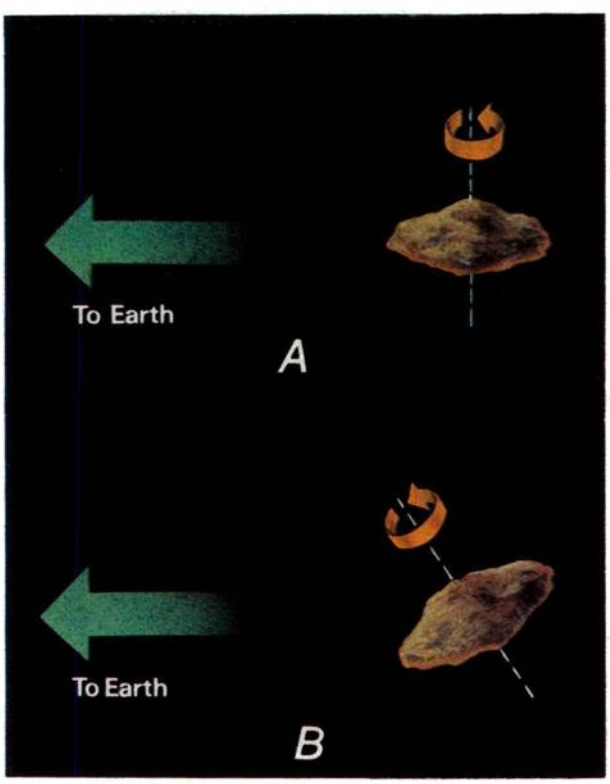
Around the time when Eros is nearest Earth it conveniently flies by Pollux, in the constellation Gemini, on the evening of Jan. 20. The circle on this map for that date is plotted for 7:00 p.m. EST. Closest approach to Pollux occurs at 10:13 p.m. EST when the brilliant star and eighth magnitude asteroid will be only 20 minutes of arc apart. The tiny world will be moving about four minutes of arc per hour — a motion that should be easy to detect after a few minutes' observation. Also at this time we are observing the irregular shaped asteroid at the angle that produces the maximum light variations. The expected range is from 8th to 10th magnitudes in about 2-1/2 hours.

Chart© 1966 Ferd. Dummlers, Verlag



Wide variations in the brightness of Eros are caused by the rotation of this irregular shaped asteroid. When we observe it end-on we actually see a relatively small surface area, and consequently Eros appears dim in a telescope. About 1-1/4 hours later we get a full broadside view of the asteroid and it appears brighter by about 1-1/2 magnitudes. The asteroid rotates completely in 5-1/4 hours.

Artwork by Victor Costanzo



Light variations caused by the rotation of the oblong asteroid Eros can vary in intensity depending on our viewing angle from Earth. Maximum variation occurs (A) when we see the potato shaped asteroid swing end-on, side-on, end-on, etc. The light amplitude is reduced (B) when more of the "upper" or "lower" sides are aimed toward Earth. Aspect A occurs during December and January. Before then we see progressively more of the south portion of Eros; after January the northern regions tip our way.

Artwork by Victor Costanzo

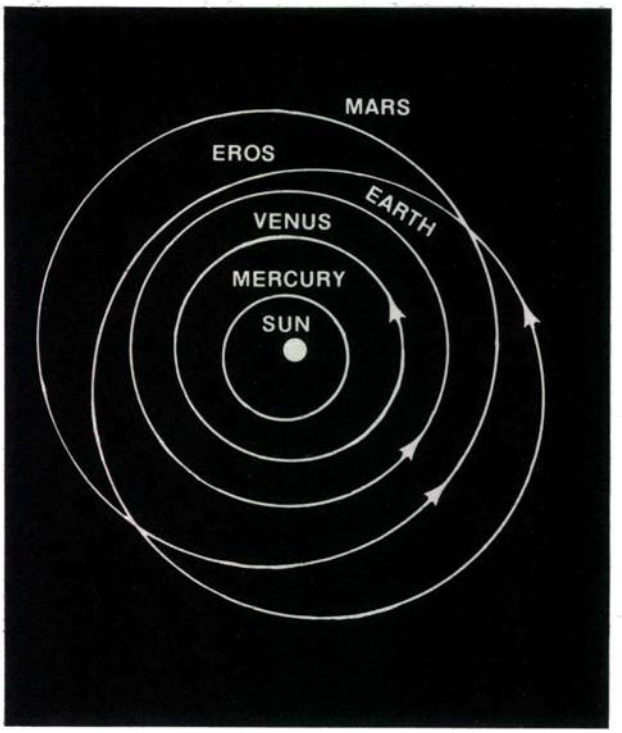
in determining the brightness. At the other end of the scale, Pallas, a main belt asteroid with a visual magnitude of about eight, is 25 times larger than Eros.

Named for the Greek god of love, Eros was discovered by Gustav Witt on Aug. 13, 1898 in Berlin. Once the orbit had been determined, it was recognized that precise observations of the

position of Eros could provide more accurate data for determining the distance to the sun and the mass of the Earth-moon system. International observing campaigns were organized for this purpose in 1931 and the results were used to obtain the most accurate solar distance available until radar experiments achieved more precise measurements in the 1960s.

Two years after Eros' discovery, Egon von Oppolzer and Ernst Hartwig noticed a regular variation in the object's brightness that ranged up to 1.5 magnitudes. Using visual and photographic measurements obtained over a period of several months, light curves were constructed which yielded a rotation period of 5 hours 16 minutes. This technique, however, provided uncertain measures of the amplitude of the light variation, which can change a great deal from month to month for a fast moving asteroid. Today, telescopes with precise setting circles equipped with photoelectric detection systems can be quickly moved back and forth between an asteroid and a comparison star. Variations as small as 0.01 magnitude can be measured with such equipment, and the time of maximum or minimum light can be determined to within a few minutes.

The favorable 1931 close approach of Eros was widely publicized and attracted the attention of experienced double star observers W. H. van den Boss and W. S. Finsen. Aiming the Johannesburg 26 inch refractor at Eros, they reported that the image appeared nonspherical (figure eight shaped) in moments of good seeing, and they were able to correlate its changing appearance with the known rotation period. However, one should not take the figure eight shape too seriously, as the angular size of Eros was only about 0.2 seconds of arc (about the same apparent diameter as Saturn's satellite, Rhea). One of the proposed research programs now being organized addresses the problem of deducing the shape of Eros from a set of precise photoelectric light curves. Even the 1975 close approach will not bring Eros close enough for the shape to be determined from direct visual observations in most telescopes, although an irregularly shaped image might be seen with a large refractor if the seeing is excellent.



EROS EPHEMERIS

Date 1974-1975 (7:00 p.m. EST)	R.A. hours	(1975) minutes	Dec. degrees	(1975) minutes	Visual Magnitude	Distance (millions of miles)
Oct. 9	5	9.1	+47	50	12.2	56.3
19	5	38.7	+50	32	11.8	49.8
29	6	9.1	+52	54	11.5	43.8
Nov. 8	6	39.6	+54	48	11.2	38.3
18	7	8.6	+56	6	10.8	33.4
28	7	34.1	+56	36	10.4	28.8
Dec. 8	7	53.5	+56	2	9.9	24.7
18	8	4.1	+54	00	9.5	21.1
28	8	5.1	+49	46	9.0	19.4
Jan. 7	7	58.3	+42	31	8.5	15.6
17	7	48.2	+31	55	8.0	14.2
27	7	40.3	+19	27	8.1	14.2
Feb. 6	7	37.5	+ 7	55	8.5	15.4
16	7	40.6	- 0	46	9.0	17.8
26	7	49.3	- 6	35	9.5	20.9
Mar. 8	8	2.3	-10	12	10.0	24.5
18	8	18.8	-12	20	10.4	28.6
28	8	38.0	-13	35	10.8	33.2

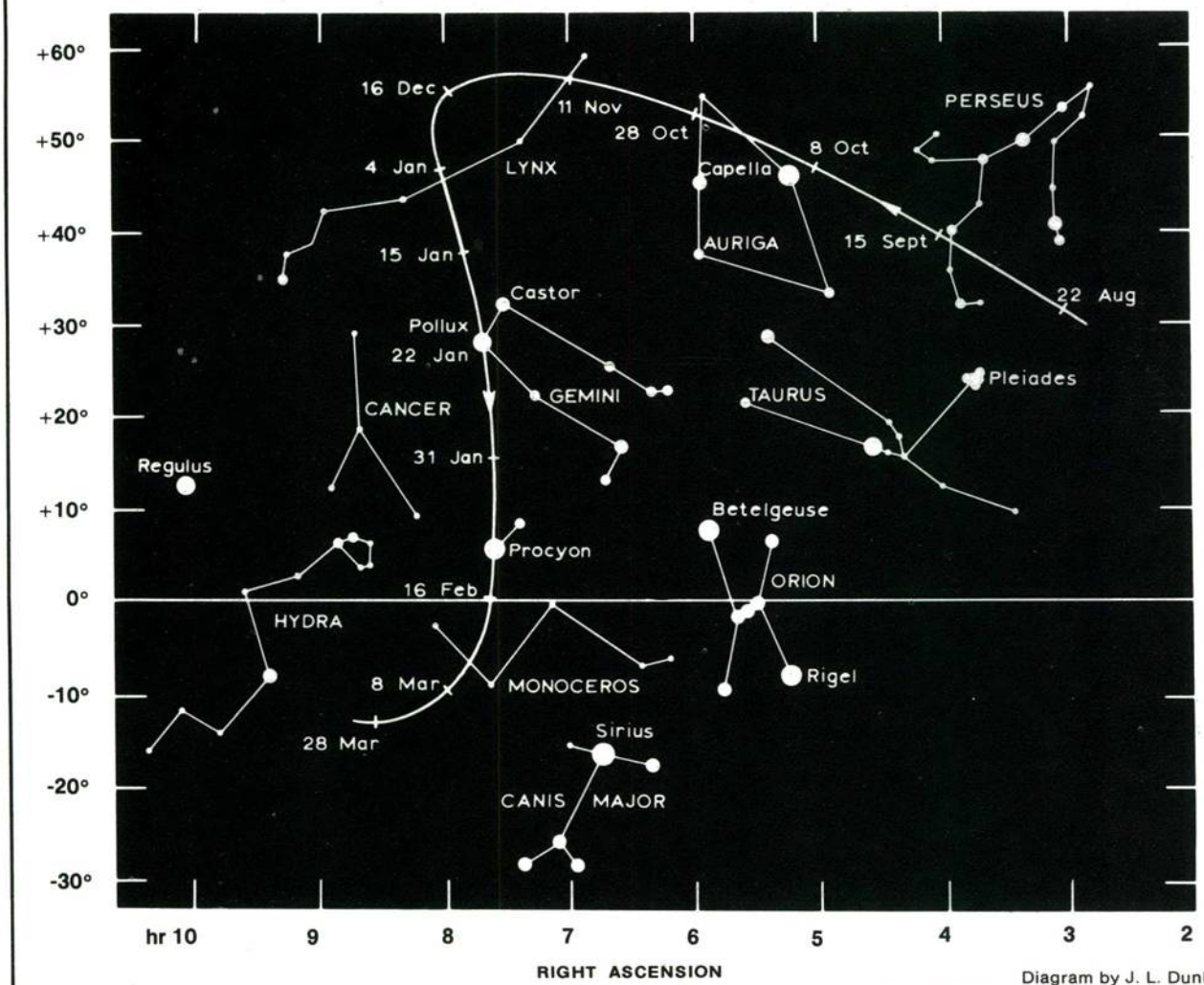


Diagram by J. L. Dunlap

This constellation chart shows the apparent motion of Eros through the sky from Aug. 1974 until March 1975. In August and September it was too faint to be observed with moderate telescopes. On Oct. 11 it passes 2-1/2 degrees north of Capella. A close conjunction with Pollux is described in the caption on page 53. An even closer pass (six minutes of arc) to Procyon on Feb. 9 is not visible from North America. During this sojourn Eros brightens from magnitude 13 in August to eight by late January, but fades again to 11th magnitude by the end of March. This variation is caused by the combined effects of the changing distance of Eros from Earth and the sun, and by the changing phase angle (sun-Earth-Eros). The next close approach of Eros will be in the year 2019.

The variation in Eros' brightness can, however, be easily detected during the few weeks around closest approach to Earth. Around that time (January and early February), we will be viewing Eros nearly broadside. This situation corresponds to maximum light variation, as you can easily verify by rotating a potato or other elongated object about its shortest body axis while looking at right angles to the rotation axis. (Illuminate the potato with a single light source near your head to get the most realistic effect.) Decreasing the aspect by tilting the rotation axis gives less light variation, and if you look pole-on, no variation is seen.

The precise aspect or tilt of the rotational axis of Eros is only approximately known. One of the objectives of a major international observing campaign by professional astronomers will be precise definition of the orientation of Eros' rotational axis. A more accurate determination of the asteroid's rotation period will also be sought by the astronomers. The high precision brightness detection techniques mentioned earlier can be combined with computer generated models which, along with a set of precise light curves of Eros, can give not only the rotation period and the axis orientation but also the relative dimensions of the shape of Eros.

Measurements of the polarization of the visible light reflected from Eros over a wide range in phase angle will be used during the "Eros Campaign" to obtain the albedo (ratio of the light reflected from a planet to the light it receives from the sun). The albedo is used along with the absolute magnitude to compute the diameter. Polarization measurements of Eros obtained by Ben Zellner of the Lunar and Planetary Labora-

tory during recent, but rather distant approaches, indicate an average diameter of 10 miles. This procedure, calibrated with a wide variety of lunar and terrestrial materials, has recently been shown to be in good agreement with diameter measurements of Deimos obtained from Mariner 9 photographs.

It should also be possible, with the improved photon-counting polarimeter of the Lunar and Planetary Laboratory, to obtain the polarization of Eros simultaneously with the light curves and thereby detect possible albedo variations over the surface. If albedo variations are found, it means that parts of the asteroid reflect light better than others — and this will further complicate the analysis of the shape.

The spectral reflectivity (the relative distribution of the light intensity over many wavelengths) may yield information on whether or not Eros is compositionally related to meteorites or other asteroids. Clark Chapman of the Planetary Science Institute in Tucson, Ariz. and Tom McCord and Carl Pieters of the Massachusetts Institute of Technology Planetary Astronomy Laboratory found the spectral reflectivity of Toro to be similar to that of certain L type chondrites — the most common variety of stony meteorites.

In 1972, Dale P. Cruikshank and David Morrison of the Institute for Astronomy of the University of Hawaii measured infrared light reflected from Eros, and calculated a diameter of 15 miles. This determination is believed to refer mostly to the longest diameter of Eros.

Hopefully, radar signals will be successfully bounced off Eros and the reflected waves analyzed to provide information on the surface roughness. R. Goldstein, D. Holdridge, and J. Lieske of the Jet Propulsion Laboratory beamed radar signals at the asteroid Toro from the 210 foot Goldstone radar antenna in California, and found fist sized and larger irregularities. By comparison the moon shows up much smoother by radar.

The results of Earth based studies such as these will provide us with new data on the size, shape, surface texture and even type of rock Eros is composed of. This information can then be used to look more deeply into the history and origin of Eros as a prelude to manned exploration of the asteroids in the decades ahead.

Lawrence Dunlap is education director at the Flandrau Planetarium in Tucson, Ariz. For the past eight years he has also been a part time research assistant at the Lunar and Planetary Laboratory of the University of Arizona. He has co-authored several articles on asteroids in the **Astronomical Journal**, *and was a contributor to* **Physical Studies of Minor Planets** *edited by Tom Gehrels (NASA publication SP-267), the most complete reference on current asteroid research available.*

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CONSTELLATION CLOSE-UP

Andromeda

by
Thomas C. Bretl

On the clearest of October nights, more than 2,000 stars are visible without the aid of a telescope. And as we gaze out into the vast, star filled sky, we may feel as though we are seeing almost to the limits of the universe. All these stars, however, are actually "close" neighbors. Although many people use the name "Milky Way" to refer only to that patchy, cloudlike band of light that arches across the summer sky, every star we see is really a member of our own Milky Way galaxy. There is, in fact, only one naked eye object in the northern skies that lies beyond this "local" spiraling system of stars. It is found in the constellation Andromeda, and is known simply as the Andromeda galaxy.

The Andromeda galaxy (M-31 in Messier's catalog) appears to the naked eye as a fuzzy fourth magnitude "star", less than two degrees west of Nu Andromedae; it is plainly visible in any size telescope. Small instruments with wide

fields of view dramatize its tremendous extent, while larger ones begin to reveal its complex structure. Its length has been measured at well over three degrees, and you will be amazed by how far you can trace the faint nebulosity which surrounds its brilliantly glowing nucleus. Several dark streaks are easily visible in a 10 inch telescope, and such detail has even been suspected in instruments of only half that aperture. No small telescope, however, can reveal M-31's true nature by resolving its individual stars. Even in our minds, it is difficult to picture this relatively small hazy spot as another entire galaxy.

The Andromeda galaxy alone would be enough to make this a favorite constellation among stargazers, but there are many other interesting objects to be found here as well. In fact, two other prominent galaxies, M-32 and NGC-205, are contained in the same low power field of view with M-31. M-32 is only 1/2 degree south of its more famous companion, while NGC-205 lies less than one degree to the northwest. Although listed at the same magnitude, M-32 is more conspicuous because of its smaller size and brighter nucleus. NGC-205 is "uniformly pale", has a low surface brightness, and may prove a difficult target for telescopes of less than four inches aperture.

Many other faint galaxies are located in Andromeda, but most are beyond the range of common amateur size telescopes. Several are in very convenient places, however, and are well worth searching for. NGC-404, for example, is situated less than 1/2 degree from Beta Andromedae, so finding it should be easy. Listed at only 11th magnitude, this elliptical galaxy seems somewhat brighter than that. Although it is small, it has a prominent nucleus and shows up well despite the glare from second magnitude Beta. In a 12 inch telescope it is especially conspicuous, even under less than ideal seeing conditions.

Rivaling M-31 as Andromeda's top telescopic attraction is the beautiful double star Gamma Andromedae. Gamma is the last in the line of stars that curves gracefully northward from the Great Square of Pegasus, and under low magnification it splits easily into a colorful pair. The components, magnitudes 2.3 and 5.1, are separated by 10 seconds of arc and have been described as gold and blue, orange and blue, and orange and green by various observers. The situation is complicated by the fact that the fainter star has a much closer, sixth magnitude companion at a distance of only 0.6 seconds of arc. This third star appears green (which may account for the blue-green color discrepancy), but the extremely

TABLE OF OBJECTS IN ANDROMEDA

Double Stars

Star	Mag.	Sep.	Colors	R.A.	Dec.
π	4.4 - 8.7	36.1"	White, blue	00^h35^m	$+33°34'$
γ	2.3 - 5.1	9.8"	Orange, blue	02^h02^m	$+42°12'$
59	6.1 - 6.7	16.7"	Yellow, blue	02^h09^m	$+38°53'$

Nebulae, Clusters and Galaxies

NGC	Type	Mag.	Size	R.A.	Dec.
205	Galaxy	9	8' x 3'	00^h39^m	$+41°32'$
221 (M-32)	Galaxy	9	3' x 2'	00^h41^m	$+40°43'$
224 (M-31)	Galaxy	4	160' x 35'	00^h41^m	$+41°07'$
404	Galaxy	11	2' x 2'	01^h08^m	$+35°35'$
752	Open Cluster	7	45'	01^h56^m	$+37°31'$
7640	Galaxy	11	11' x 1.4'	23^h21^m	$+40°42'$
7662	Planetary Nebula	9	0.5' x 0.5'	23^h25^m	$+42°21'$

Epoch 1970

small separation involved presents a very stiff test of resolution for both your telescope and the seeing conditions. The two brighter stars are well seen in almost any telescope, however, and are sure to provide a memorable — if not breathtaking — sight the first time you see them. Gamma is a very strong contender as the most exquisite double star anywhere in the heavens.

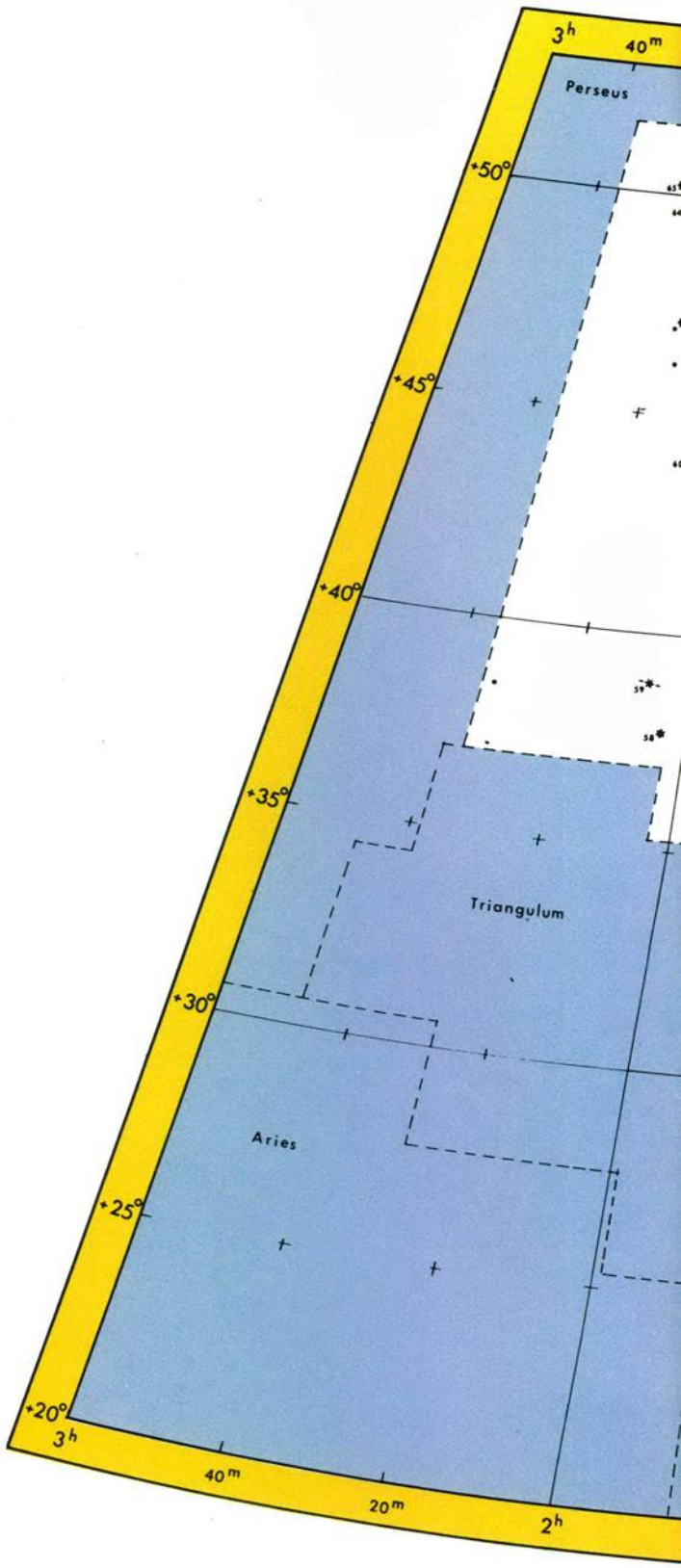
Other doubles in Andromeda include Pi Andromedae and 59 Andromedae, but both are rather wide pairs with colors that are much more subtle than those of Gamma. Nevertheless, they are easy to locate and provide a pretty sight under low magnification.

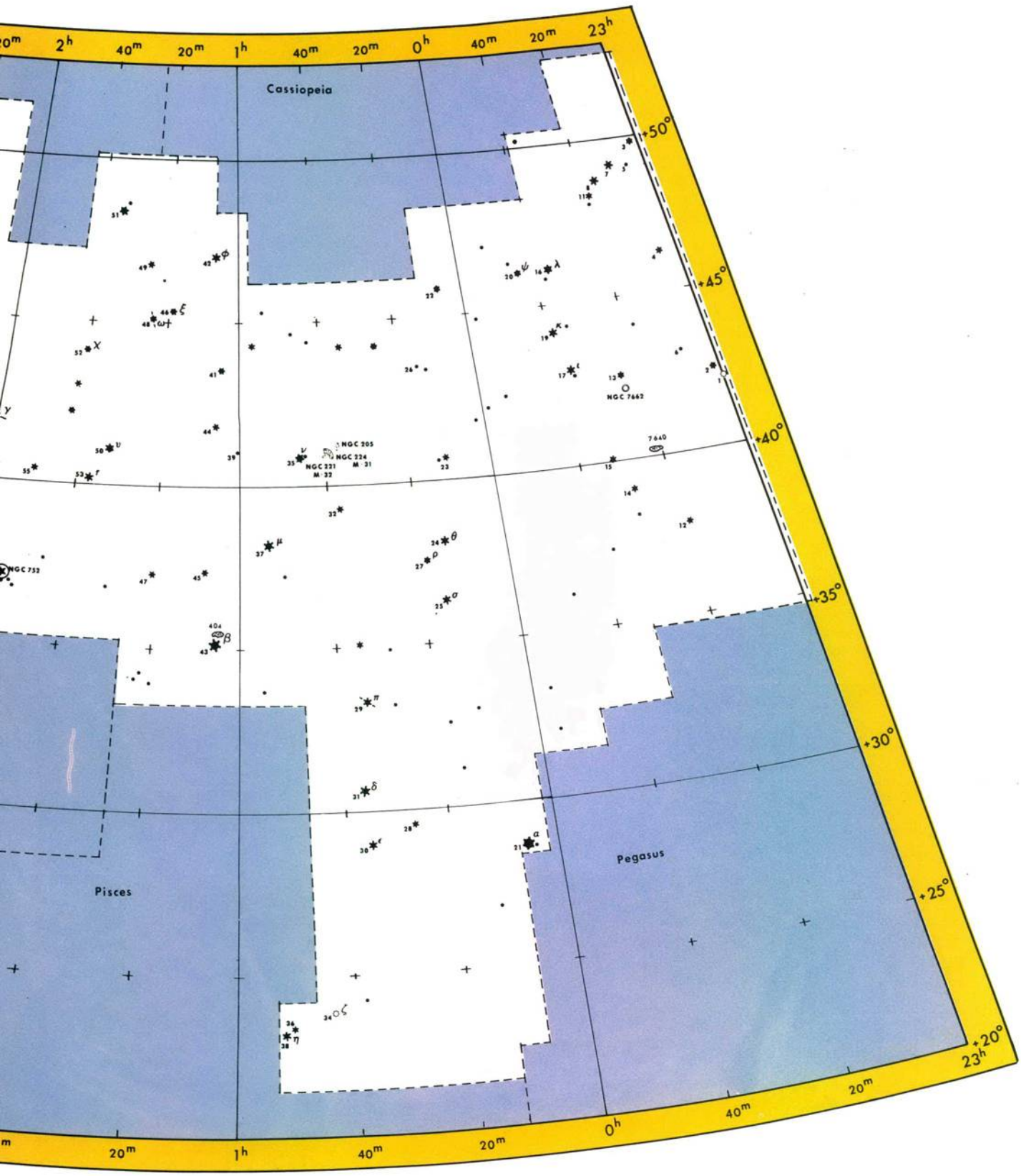
Often overlooked in the western part of Andromeda is an object much different than any of those already described. It is NGC-7662, an interesting planetary nebula. You can find it by first drawing an imaginary line from Alpha to Beta Pegasi (the western two stars in the Great Square) and then following it an equal distance north. There you will find third magnitude Omicron Andromedae; the nebula lies just five degrees to the east, in the same low power field with 13 Andromedae.

Once located, NGC-7662's brightness is sure to impress you. When viewed at low power, it is almost like a ninth magnitude star. At a magnification of 60x, however, it becomes a definite bluish disk, and at higher powers it becomes obviously ring shaped when viewed in a 10 or 12 inch telescope. Its central star, although listed in some atlases as 12th magnitude, appears beyond the range of even this size intrument.

Those observers who enjoy the challenge of faint, elusive nebulae may want to spend some time hunting for NGC-7640. This galaxy is located only two degrees southwest of NGC-7662, but its listed 11th magnitude certainly exaggerates its true visual brightness. Unfortunately it is large and elongated, and like NGC-205, it lacks a prominent nucleus. Don't bother looking for it if the skies are not very transparent. Even then, it is a tough one!

A night spent in Andromeda should probably end as it began, with another look at the great galaxy. Man has often philosophized about the possibility of universes existing within universes, of orbiting electrons being like the planets revolving around the sun, or of whole new worlds existing on the head of a pin. A naked eye glance at this amazing galaxy, however, is a glimpse of reality that is even more startling than such speculation. For here is a small fuzzy "star" that seems totally insignificant when first seen among its brighter neighbors; yet it contains within it as much as everything else we see tonight... and more. And it is only one of billions of other Milky Ways!





Stellar Magnitudes -1 0 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 & fainter

Diffuse Nebula Double Stars Variable Stars

Galaxies Planetary Nebula Open Star Clusters Globular Clusters

Map by Raymond G. Coutchie

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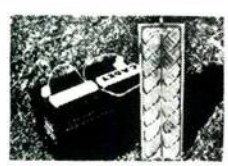

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